ROMANCE OF THE ROCKS

PEEPS AT NATURE

Isabel Mary James.
W.S.S.G.

PEEPS AT NATURE

EDITED BY
THE REV. CHARLES A. HALL, F.R.M.S.

VI. THE ROMANCE OF THE ROCKS

UNIFORM WITH THIS VOLUME

WILD FLOWERS AND THEIR WONDERFUL WAYS

BIRD LIFE OF THE SEASONS

BRITISH LAND MAMMALS

BRITISH BUTTERFLIES

BRITISH FERNS
CLUB-MOSSES AND HORSETAILS

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DUNOTTAR CASTLE, PERCHED ON UPTURNED EDGES
OF OLD RED SANDSTONE CONGLOMERATES.

THE ROMANCE OF THE ROCKS

BY

REV. CHARLES A. HALL, F.R.M.S.

AUTHOR OF "THE OPEN BOOK OF NATURE," "WILD FLOWERS AND THEIR WONDERFUL WAYS," "HOW TO USE THE MICROSCOPE," ETC.

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TO THE

CHERISHED MEMORY

OF

R. M. P.

INTRODUCTORY NOTE

This further volume of the "Peeps at Nature" Series is intended to introduce the reader to the study of the rocks. It is obviously not a compendium, but essays to be a simple and popular introduction, which, it is hoped, will prove to be sufficiently interesting to induce the reader to follow up the study of geology in more minute detail. The author recommends the reader who is fired with enthusiasm for geological research to consult, among others, the following books: "A Class-Book of Geology," Sir Archibald Geikie; "Geology for Beginners," W. W. Watts; "The Earth and its Story," A. R. Dwerryhouse; "The Changeful Earth," G. A. J. Cole; "Geology," J. W. Gregory; "Worlds in the Making," Arrhenius; "Extinct Monsters and Creatures of Other Days," H. N. Hutchinson; "Extinct Animals," Sir E. Ray Lankester; "The Natural History of Coal," Arber.

CHARLES A. HALL.

Paisley, 1912.

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LIST OF COLOURED AND PHOTOGRAPHIC ILLUSTRATIONS

* These eight illustrations are in colour; the others are in black and white.

GEOLOGICAL SKETCH-MAP OF THE BRITISH ISLES.

THE ROMANCE OF THE ROCKS

CHAPTER I

IN THE BEGINNING

The story of the rocks which form the crust, or lithosphere (Greek, *lithos*, stone ; *sphaira*, a sphere), of the earth is fraught with romantic interest ; it appeals to the imagination, arouses the sense of wonder, and is conducive to humility and reverence. Quoth Euripedes :

> "Happy the man whose lot it is to know
> The secrets of the earth. He hastens not
> To work his fellows' hurt by unjust deeds,
> But with rapt admiration contemplates
> Immortal Nature's ageless harmony,
> And how and when her order came to be."

The term "rock," as used in this volume, embraces all the materials which enter into the composition of the earth's crust, whether they consist of solid rocks of igneous or sedimentary origin, shingle, pebbles, sand, clay, mud, or surface soil. It is to the romance of the formation of the varied materials of the earth's crust, and of the evolution of the earth from its remote beginning to its present condition, that the following pages will be devoted.

" The present is a key to the past." We have every reason to conclude that the forces and laws controlling the universe to-day have operated from the beginning of time; from what is happening to-day we may form an idea of what has happened in the past.

Is anything happening now which gives us an indication of the origin of the earth, and enables us to form an idea of the manner of its formation? It is highly probable that there is. Sweeping the heavens with the telescope, astronomers have discovered thousands of cloudlike masses which are called "nebulæ." Most of them are so exceedingly remote that they can be discerned only with the most powerful instruments; others can be observed with the aid of a small telescope, or even a field-glass; at least one, the spiral nebula in the constellation Andromeda (Plate II.), can be seen with the naked eye. These remarkable objects exist in a great variety of forms. The larger ones are irregular in shape, with brighter spots within their mass; they also display dark spots and rifts. Some nebulæ are spiral, and may be likened to a catharine-wheel; others are ring-shaped. Then there are nebulous stars, which consist of bright centres surrounded with nebulous matter. Probably all nebulæ are in motion. It is conjectured that they consist either of vast masses of gaseous matter in a state of incandescence, or of a swarm of fragments of metals, principally iron and nickel. Not improbably they are formed of the wreckage of worn-out suns, which have collided with terrific impact and been

smashed to fragments. As meteors fall to our earth, so may moons, no longer able to hold on their courses, crash into their respective planets ; the planets, in their turn, may in due time fall into the sun ; and the sun, having radiated its heat, will grow cold and dark, and rush through space until it collides with another dead sun. As a result of the impact, the colliding suns will be smashed to fragments, and great heat will be generated : the final result will be a nebula. And what of the nebula ? It is thought that its widely diffused substance will condense into a solar system, and thus a new order will be established out of the wreckage of dead worlds. The nebulæ we see in the heavens to-day may be regarded as masses of world stuff in the process of becoming solar systems, and there is good reason to think that they present us with the key to the interpretation of the original formation of our earth. Ages upon ages ago, it may have been a hot nebula, whether of incandescent gas or swarmed metallic fragments, which then filled much vaster space than its solid matter does now. In process of time, the mass condensed into a sphere with a solid crust enclosing a highly heated magma or core. The thin crust at first formed would over and over again be split and rent by gases, and streams of molten matter would rush through the fissures on to the surface. Later the crust would be thicker, and the discharges from the heated interior would proceed on a less magnificent scale ; volcanoes would appear, through which water vapour and carbonic acid would escape.

Then the time would arrive when water would condense, and oceans, or a universal shallow sea be formed ; and in that water, the first life-forms, plants and animals of the simplest types, would in due course appear.

"The earth was without form and void," so the Biblical writer has it, and Tennyson declares :

> "This world was once a fluid haze of light,
> Till towards the centre set the starry tides,
> And eddied into suns, that wheeling cast
> The planets."

Milton's words may also be applied to the nebula :

> "A dark,
> Illimitable ocean, without bound,
> Without dimension, where length, breadth, and height,
> And time and place, are lost ; where eldest Night
> And Chaos, ancestors of Nature, hold
> Eternal anarchy, amidst the noise
> Of endless wars, and by confusion stand."

The nebular theory of the origin and formation of solar systems is usually placed to the credit of Laplace, but in justice it ought to be said that it was anticipated by Swedenborg, the Swedish scientist and philosopher. It is a magnificent and fascinating hypothesis which almost commands assent. We are not in possession of all the necessary knowledge for its justification ; no one has proved that the nebulæ in the heavens are stars in the making ; but there is a consensus of opinion towards that conclusion. One thing is certain : however our earth originated, it is exceedingly hot in the central mass, as is evidenced by geysers and volcanoes, and by

the fact that the deeper we penetrate into its crust, the higher becomes the temperature.

We do not know whether the nebula from which the earth was formed was originally gaseous, or a swarm of metallic fragments. If it was gaseous the first climate of which we have any indications would be much hotter than we have evidence of. In point of fact, the earliest known climate differed very little, if anything at all, from that we experience in the twentieth century.

What is the present nature of the earth's central core? Very little can be said in answer to this question. We know that it is heavier, mass for mass, than the crust; that, in fact, it is about twice as heavy: we opine that it is intensely hot. At one time it was thought that it was in a gaseous condition; but this is now deemed unlikely, and opinion favours the idea of a viscid liquid which may be likened to asphalt. A gaseous condition could hardly be expected under the conditions of the tremendous pressure of the crust.

We are also in ignorance as to the actual thickness of the crust; it has been variously estimated as from twenty to forty miles; but it is certain that the crust is small in mass in comparison with the central core. It is not even as thick as the peel of an orange in comparison with its juicy matter. Assuming that the crust's thickness is twenty miles, and taking the diameter of the earth as nearly 8,000 miles, it is easy to see that the crust forms a small fraction of the earth's mass. For an orange with its peel to proportionately represent the

core of the earth with its enveloping crust, it would need to be about 25 inches in diameter, the peel being $\frac{1}{8}$ inch thick.

The student of geology (Greek, *ge*, earth ; *logos*, science) is naturally interested in theories of the origin of the earth and the nature of the central core, or barysphere (Greek, *barus*, heavy), but his interest is chiefly centred upon the crust, for there he is indeed on solid ground, and in a position to read the record of the rocks. And a remarkable record it is—a chronicle of ceaseless integration and disintegration, eternal change and rearrangement ; a story of lost continents and new land surfaces, of hills laid low and exalted valleys, of mountains cast into the sea. There may be some stormy passages in the record, but on the whole it is a chronicle of peace. Titanic forces have operated with gentleness and patience ; changes have been gradual ; the most sublime results have been affected by the long processes of time.

Fortunately more pages of the record are available for reading than unthinking persons might imagine. The successive layers of the earth's crust have not been allowed to remain in their original positions, the older layers beneath and the newer layers above capped by the most recent. Had they remained so our knowledge of what lies beneath the surface would be restricted to that obtained by means of mines and borings ; and as our deepest mines are less than a mile in depth, the information would be very limited. But the crust of

the earth has been subjected to much disturbance ; it has been fractured and folded ; old strata have been pushed up to the surface and tilted at an angle, so that we may walk across their upturned edges. It is calculated that beds of strata containing fossil traces of the life-forms of past ages have been exposed to the extent of about fourteen miles, which is no small proportion of the entire crust.

It is usual to think and speak of life as an attribute of living creatures, plants or animals ; and to regard material substances as lifeless. We should hardly say that matter has life in itself, or can be declared to be alive in any sense ; but we may surely conclude that the forces, energies, and affinities evidenced in the making of the universe, which hold the stars in their courses and cause atom to cling to atom, are activities of life, and manifestations of Creative Power.

CHAPTER II

DESTRUCTION AND CONSTRUCTION

The rocks which first formed the crust of the earth were made of molten material cooled and solidified ; they were igneous, or fire-formed ; and all igneous rocks, whether those originally formed, or those which have been intruded into the crust, or have issued to its surface, are called by the geologist "Primary." It is well to remember that all rocks other than primary owe

their substance to the primary rocks, the materials of which they are formed having been originally derived from them. Primary rocks bear ample evidence of their igneous origin; they are either crystalline or glasslike; they commonly occur in huge masses without stratification. Rocks which are made of material derived from broken-up primary masses are called "Secondary." They occur in beds or layers, and are also called "Stratified." They are made of fragments of primary rocks, also of the inorganic parts of animals and plants—their shells and skeletons. Let it be noted that the inorganic matter used by animals and plants was derived originally from the primary rocks. Fossil remains of plants and animals occur in secondary or stratified rocks; they need not be looked for in those of an igneous origin.

When the crust of the earth arrived at a proper condition of stability and temperature for water to condense upon it and form an ocean or oceans, the rocks were all igneous; no secondary rocks had been deposited. The surface, doubtless, had numerous inequalities, but we do not know whether they were equivalent to the mountain heights and ocean depths which obtain to-day. Perhaps there may then have been a universal shallow ocean unbroken by continent or island, or, in places, masses of primary rocks may have appeared above the surface. At any rate, dry land came into evidence in due course, and as soon as it appeared it became subject to those devastating attacks which led to its partial dis-

integration, and to the formation of secondary rocks from its fragmental material, or débris. In the primeval ocean lowly plants and animals came into being, and they extracted inorganic substances, derived from the land and held in solution, from the water, and converted them into shells or skeletons which, when the life was withdrawn from them, fell to the bottom of the ocean and accumulated, eventually being consolidated into rock.

Because the present is a key to the past we can ascertain from what is going on to-day what happened to that primeval land-surface. It was subjected to alternations of temperature ; in a glaring sunshine its surface became very warm ; at night the heat gained during the day was dissipated, and the surface grew cold. Rains descended upon it, and streams followed the course of surface inequalities, thus finding channels leading to the sea. Sheets of water accumulated as lakes and tarns ; wind beat upon the land, and the sea attacked the cliffs. Vegetation crept up from the sea and became adapted to a terrestrial existence ; land animals of a certain order, which we need not attempt to define, found an abode. Probably geysers shot hot water into the air, volcanoes sent out streams of lava and clouds of ashes, and the rocks were rent in places by earthquakes. We need not think that in those primeval days volcanoes were much more active, or earthquakes more severe than now ; nor need we imagine awful cataclysms and titanic upheavals as

occurring then in a degree more alarming than those of which we have had actual experience. Change and rearrangement are the order of Nature, but they take place slowly and through vast periods of time.

A cynic once declared that the ways of Nature are like a game of skittles—things are set on their feet only to be knocked down. We should hardly speak in such irreverent terms; but there can be no question that all things "have their day and cease to be." This is true of continents and mountain chains, of plants and animals. But the cynic, as well as the writer of the lines "Change and decay in all around I see," failed to point out that "the old order changeth, yielding place to new." New worlds are formed out of the débris of old ones, and new continents are constructed of the fragments of ancient land-surfaces.

Let us beware lest we attribute more than is due to earthquakes and volcanoes. Their activity is local and spasmodic, and they have been far less potent in the changes which have taken place in the history of the crust of the earth than is commonly supposed. Persons unacquainted with the real causes of earth sculpture are generally disposed to account for precipices and rock-strewn ravines, by imagining gigantic upheavals in past ages; they fail to appreciate the fact that frost and wind, running water and ice, have accomplished more wonderful results than any earthquakes of which we have records.

On December 14, 1910, an earthquake shock was

North

(1)

(2)

1) Great Nebula in Andromeda. Photograph by Dr. Max Wolf

2) The Goatfell Range from King's Cross, Arran

Note the rugged manner of weathering in comparison with the rounded hills in the foreground and middle distance

felt in Glasgow and its immediate neighbourhood. My own house, near Paisley, was shaken, and I heard a noise as of an explosion. This earth tremor caused much alarm, but did no serious damage, and, as far as the eye can descern, left no visible trace of itself on the ground shaken. It was probably caused by a slight slip in some strata along the line of an ancient fault. On August 20, in the same year, there were torrential rains in the West of Scotland and elsewhere. I was then staying in the Island of Arran, where, on the morning of the day mentioned, the streams flowing from the hills were in a normal condition. But rain fell so heavily in the course of the day that in the evening some streams overflowed their channels, and all in the district were in exceptionally heavy spate. It was a splendid opportunity for observing the power of running water. I saw huge masses of soil removed from banks of streams and washed seawards. Boulders, some of them weighing many hundredweights, were rushed along the channels, making a grinding noise as they proceeded, and I noticed masses of rock being lifted by the water and literally hurled into the sea. A track of dirty fresh water, fully a quarter of a mile in length could be seen, proceeding from one large stream, in the sea itself—a veritable fresh-water river in a channel of salt water. Elsewhere, bridges were swept away and much damage was done. In a few hours hundreds of thousands of tons of soil, sand, gravel, and larger rock stuff were washed from the land and deposited in the sea.

Such spates occur occasionally, and when they do happen their effects are easily observed; but we must bear in mind that under normal conditions streams of running water are constantly engaged in carrying débris seawards. The earth tremor felt in Glasgow caused alarm; the August spate aroused wonder, not fear. Yet so far as geological effects are concerned, the spate produced the greater results.

It may be objected that the Glasgow earth tremor mentioned was too insignificant for purposes of comparison. Let us, then, briefly consider the famous San Francisco earthquake which caused such havoc and alarm in April, 1906. The damage done to property was enormous and many lives were lost. The principal effect of the earthquake was this destruction of property and life. But what difference did it make to geography? How much material did it remove from the land and cast in the sea? Did it excavate gorges and ravines? Did it hurl rocks into the Pacific Ocean? So far as I can learn this tremendous earthquake, the movement of which was mostly horizontal, left traces of itself over a distance of nearly two hundred miles. These traces consisted of slippings of strata along a line of fault; in some places the ground was cracked and a species of furrowing occurred. The courses of roads were dislocated, and even fences were snapped vertically and portions still standing were left several feet apart.

Now, while the whole civilized world was horror-

struck by the San Francisco disaster, running water everywhere was busily engaged, as it always is, in carrying detritus seawards. Our own River Thames is said to carry over half a million tons of mud, etc., to the sea every year ; during the eventful day in San Francisco it would probably transport upwards of 1,400 tons, and this figure must necessarily represent a minute fraction of the material transported conjointly by all the rivers of the world. The disturbance by the earthquake was an event of a day ; it may not recur for years to come, but running water is at work all the time, and as a geological agent it is vastly more effective than earthquakes.

Professor Milne, the inventor of the seismograph—an instrument for recording earthquakes—and an enthusiastic student of these phenomena, declares that a little earthquake happens somewhere on an average every fifteen minutes, and great earthquakes occur about every four days. These big disturbances do not seem, however, to trouble populated districts, except on rare occasions, or we should hear more about them. But the geological effects of these almost constant disturbances is small. In brief, we have to regard earthquakes, not as causes, but rather as being themselves effects of those gradual earth-movements which are responsible for faulting the rocks, and for the slow uplift of land-surfaces. These movements, except in rare instances, are imperceptible during the life-span of a man ; they occupy immense periods of time, and have a geological

importance to which we shall give some attention in what follows.

Volcanoes have been active in all geological epochs and have produced important results. Yet their activity has always been fitful and local. Vesuvius may have buried Pompeii in ashes, but it is seldom so alarmingly active. While volcanoes in restricted areas are bringing up material from below the crust of the earth and depositing it on its surface, other denuding agencies, universally at work, are removing material from the land at a rapid rate.

As we shall see, our lovely valleys, glens and dales, and the cañons, gorges, and ravines of the world, have been cut by erosion, and the most magnificent scenery in the world is caused, not by sudden, titanic upheavals of the earthquake order, but by less alarming forces.

The reader will gather from the foregoing that once a land-surface is raised above the waves, it is immediately attacked by destructive elements and forces. The first land-surface, of igneous rock, was so attacked in primeval time. It was cut, carved, and sculptured ; it was slowly reduced in height, and girth, and mass. But the fragments to which it was reduced were not lost or wasted. Even its substances dissolved in water were yet to play their parts in geological results. The materials transported from the early land were deposited in lake and sea, there to form secondary or stratified rocks, which in subsequent ages were uplifted, and in

(1) 

(2) 

(1) Black Cave, Arran (2) Sandstone resting on Shale

their turn subjected to the ravages of time. We are reminded of the lines learned in early years:

> "Little drops of water,
> Little grains of sand,
> Make the mighty ocean,
> And the beauteous land."

A pebble on the beach is a little thing that we may pick up, hold for a moment, and then lightly throw aside; but could it speak, it might tell us of the wonderful romance of the rocks, in which the forces or destruction and construction work together so marvellously, and with such grand results.

CHAPTER III

EARTH-MOVEMENTS

The gradual earth-movements, to which brief allusion has already been made, demand closer consideration, especially when we realize the important part they have played in the story of the rocks, in causing great and minor faults, in elevating mountain chains and continental areas, and depressing ocean beds.

The tremors and earthquakes constantly recorded by the seismograph clearly indicate that the crust of the earth can never be said to be in a state of rest; there is movement somewhere every day and every hour of the day. But how is this movement to be accounted for? We must confess great ignorance concerning the

matter. The ebb and flow of tides, changes of atmospheric pressure and temperature, the constant removal of material from land-surfaces and its accumulation in thick beds in the sea, involving shifting of weight and pressure, may be external factors in the movements; but it is generally thought that the principal cause is internal. It is assumed that the core of the earth is gradually losing heat, and consequently contracting. In that event the crust may be regarded as a loose envelope surrounding the contracting core, with a tendency to wrinkle, fold, and undulate. Other speculators conjecture that between the hard crust and the solid core there is a ring of molten material at high temperature, tending to expand, and thus resisting the pressure of the crust and causing it to undulate and wrinkle; the same speculators connect this ring of molten matter with volcanoes. However, still other thinkers advance arguments against the possibility of there being a continuous ring of molten stuff beneath the crust; they suppose it to exist in disconnected patches. Whatever justification there may be for these conjectures, it may be assumed that the crust of the earth is regularly disturbed from below, and subjected to much pressure and some terrific impacts from above. Internal and external forces which we have some knowledge of, in addition to others of which we are in ignorance, combine to bring about movements of the crust which, in their cumulative effects, produce remarkable changes in the geography of the world.

WASTWATER FROM STRANDS. NOTE SCREES ON RIGHT.

Fossils in the Mountains

The crust of the earth may be likened to the rind of an orange which has been kept some length of time and lost its freshness. In such an orange the pulp contracts, the skin becomes dry, and, being too large for the diminished pulp, it presents a wrinkled appearance. The wrinkles and the hollows between them may be taken to represent mountains and valleys, and large depressions of the rind will suggest ocean beds.

If we ascend mountains and there discover stratified rocks containing numerous fossil remains of creatures of the sea, we are bound to conclude that the animals these fossils represent once lived in the sea, and that the strata containing the fossils were formed in the sea. These fossils were not spirited from the sea to their present position by fairies. Now, as a matter of fact, we do find stratified rocks containing fossils of marine organisms at various elevations above sea-level; they are to be seen as far above the sea as 10,000 feet. Not to go beyond our own British Isles for evidence, we point to the great development of limestone in Derbyshire, where there are fine heights and lovely dales. This limestone was unquestionably formed under marine conditions, and certainly contains numerous fossils of marine origin. At the time when the Derbyshire limestone was in process of formation, the geography of the Continent of Europe was very different from that of the present day. There was a great area of land which included small tracts of the East and North of Ireland, the whole of the Highlands of Scotland, and stretched

across what is now the North Sea to Norway. Land also stretched in a narrow belt from the East of Ireland, across Wales, and the English Midlands to the Continent. North and south of this belt there was sea, broken by small islands in what is now the South of Scotland, the Lake District, and the Isle of Man. It was in this sea that the strata of Lancashire, Yorkshire, Derbyshire and other counties were laid down, as well as the rocks of the South of England and parts of the Continent. The fact that these strata are now high and dry is due to gradual earth-movement, which has been responsible for not only uplifting the rocks, but also for depressing parts of the ancient land-surfaces, so that they are now submerged beneath the waves.

The wonderful fiords of Norway, and the beautiful sea-lochs of the West of Scotland are really valleys cut out of the land-surface, and so depressed by earth-movements that they are now flooded by the sea. When the land was at a higher level those valleys were coursed by streams and glaciers. In the West of Scotland, and in some of the Norwegian fiords, there are raised sea-beaches at various levels ; they occur as high as 100 feet above present sea-level in Scotland. They prove that the sea once broke upon beaches which are now high and dry, and that since the land was so depressed as to make valleys into inlets of the sea, there has been a succession of elevations of the areas concerned. The level of the sea is constant ; it never changes ; so the raised beaches can be accounted for

only by earth-movement. On the east coast of Scotland, in Dornoch Firth, there are raised beaches at five levels—namely, about 15, 25, 50, 75 and 100 feet. These levels indicate successive elevations of the coast, with periods of rest in the movements. There is every reason to believe that the uplifts involved have occurred within comparatively recent time. On Plate III. you have a picture of the monster cave in the cliffs at Bennan Head, in the south of Arran; this cave was undoubtedly formed by the action of the sea, but since its formation the island has been raised, and now the cave is not reached by the sea. In the same island there are several caves formed by wave action, which are now raised many feet beyond the present beach. Terraces cut in solid cliffs of rock by wave action, and now much elevated above the sea, occur in many places. They are particularly noticeable on the south coast of Mull and on the east of the Isle of Jura. They are to be seen in the rock shelves (*seter*) of Norway, and in the West of the United States, where they have been found over 1,200 feet above the sea. Charles Darwin, in the course of his observations on the Pacific coast of South America, found raised beaches at various levels from about 80 to upwards of 1,300 feet; and from certain human vestiges discovered, he concluded that the land had been raised in that area about 85 feet since man occupied the country. As a matter of fact, the west coasts of North and South America are at present undergoing elevation due to a continuation of the

uplifting movements which formed the great mountain chains of the West, and with which a series of earthquakes at San Francisco may be connected. In the neighbourhood of that famous city strata of a marine nature have been raised, high and dry, to an elevation of about 2,000 feet.

The ruins of the Temple of Serapis provide valuable evidence of past earth-movements. This temple was built about 2,000 years ago. It was erected at Pozzuoli, nearly at sea-level. In course of time, the temple was submerged, owing to a depression of the ground. The roof disappeared, and the floor was covered by some feet of mud and sand. But some of the great pillars were only partially submerged, the extent of their submergence being evidenced by a zone of holes bored by certain boring molluscs. Beyond this zone the pillars show signs of attack by the atmosphere. The land on which the ruins stand is now raised clean above the sea. During the submergence the sea would reach farther inland than it now does. These ruins show that in less than 2,000 years, an area of land has been dipped into the sea, and again elevated beyond its level.

Sir Charles Lyell, the famous geologist, noted many years ago that, in the South of Sweden, streets had sunk beneath the sea, and that on the same coast, in other places, barnacle shells could be seen over 100 feet above sea-level. In 1792 some rocks in Sweden were marked; they were examined a century later, and found to have

been elevated about 3 feet in the course of the intervening century. This is a considerable rate of elevation, and it does not require a great stretch of the imagination to see what enormous changes in geography would occur in the course of a thousand years if such a rate were maintained. But the probability is that there are always long periods of rest in such uplifts, and that the movement is in time arrested or transferred to other areas.

The great mountain ranges of the world are due to the folding and wrinkling of the earth's crust. The very high ranges are the youngest, and they are being gradually broken up and reduced. It is estimated that many thousands of feet have been removed from the Welsh heights, which are much older than the Alps. Snowdon is the reduced stump of a once exceedingly high mountain. In the Scottish Highlands we have mere stumps of great heights reduced by wear and tear ages ago. Since that reduction they have been depressed beneath the sea, there covered with deposits, and then, at a later stage, raised as a tableland. This tableland has since been dissected by the agencies which make valleys and fiords, and in the existing heights we discover traces of some of the oldest mountains of the world. The Alps, the Himalayas, and the Andes are the results of comparatively recent uplifts.

A person who has not given consideration to the matter may be inclined to be somewhat sceptical about an uplifting power capable of raising the Alps, or other

heights with which he may be familiar. But it is not difficult to show that these elevations are really very insignificant when they are compared with the bulk and dimensions of the earth. We have to remember that the earth is about 8,000 miles in diameter, and that Mount Everest, the highest mountain in the world, is but $5\frac{1}{2}$ miles high. In relation to the diameter of the earth, this mountain is hardly comparable to a pimple on one's face! Reverting to our former simile—the orange, which, to represent the crust of the earth enveloping its central core, would need to be 25 inches in diameter, with a peel $\frac{1}{8}$-inch thick—on such an orange Mount Everest would be represented by an eminence no greater than $\frac{1}{60}$-inch. The ocean, which is said to be about five miles deep at its profoundest depths, would have its deepest part represented by a very slight depression.

We have abundant proofs of ancient earth-movements in the faulted, folded, and altered rocks which are to be seen in various parts of the British Isles.

Examine closely the Scottish portion of the geological map on p. viii. Two lines may be detected which mark the north and south boundaries of the great Midland Valley of Scotland. One line runs south-west from Stonehaven on the east coast to Loch Lomond and the Clyde on the west. The southern line proceeds from Dunbar on the east almost parallel with the northern line. Between these two lines we find a belt of Old Red Sandstone and Carboniferous rocks, the

latter containing the mineral wealth of Scotland in the form of coal, iron, oil shale, etc. South of the northern line we find the Southern Uplands, with rocks of great age; and north of the northern line we have the exceedingly ancient rocks of the Highlands. The rocks of the central belt are more recent than those to their north and south. Now, these two lines are great dislocations, known as "faults"; they are due to a remarkable series of earth-movements, by means of which the valuable strata of the Midland Valley have been lowered some thousands of feet, and, incidentally, preserved for our benefit. Had it not been for the depression of these wealth-yielding rocks between the Highlands and the Southern Uplands, they would probably have been swept away by Mother Nature's besom, and Scotland would have been deprived of most of its great industries. Let it be understood that the faulting took place very slowly indeed; any part of the process would not be observable in the span of a human life. A visitor to Stonehaven is able to see for himself that the great northern dislocation has caused the Old Red Sandstone strata to be literally thrown on end for a distance of about two miles to the south. In the neighbourhood of Dunnottar the conglomerates of that formation have been worn into a series of headlands projecting seawards. The ruins of that ancient stronghold, Dunnottar Castle (Plate I.), are situated on one of these headlands.

Fig. 1 represents strata which are dislocated by a

fault. The straight line is the plane of fault; the rocks to the right have been lowered by earth-movements, and, in the progress of their depression, they have had their beds bent upwards, while the stress caused by the dislocation has also been instrumental in bending the beds to the left downward along the plane of fault. This diagram helps us to understand why the Old Red Sandstone strata just referred to have been turned on end by the great Scottish dislocation.

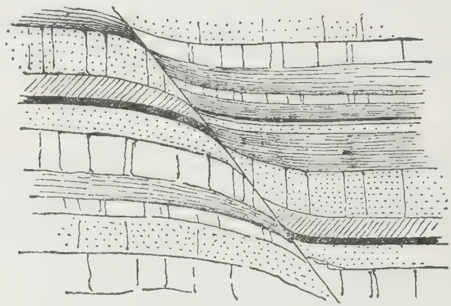


Fig. 1.—Diagram of Fault, showing strata bent along the plane of fault.

The phenomenon may be illustrated by a pie in a pie-dish, into which the crust has sunk, the sinking process causing the edges of the crust to be turned upwards at the sides of the dish.

Faults give miners much trouble. They may be working merrily enough along a seam of coal, but one day discover that the seam comes to an abrupt end. Earth-movement dislocates seams, and also tilts and folds them back. Look at Fig. 2 and observe how

DOVEDALE DERBYSHIRE

the strata are faulted. The dotted bands represent beds of rock which are easily permeated by water ; the darker portions indicate strata which water cannot permeate. Water percolates through the permeable rock and collects on the surface of the impermeable, so that it can be readily obtained by sinking a well at the place shown in the diagram on the right of the plane of fault. But the fault has materially lowered the water-bearing

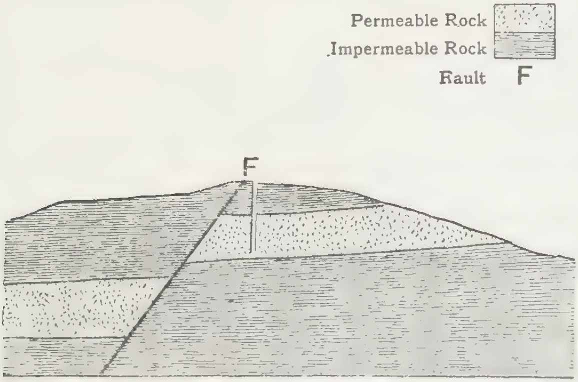


FIG. 2.—EFFECT OF FAULT ON POSITION OF WELL.

rock to the left, and anywhere on that side of the fault plane, a well would need to be considerably deeper than on the right. Suppose the dotted bands represent a faulted coal seam, you can easily understand the trouble it would give to miners.

As this volume is not intended to be technical, I shall not attempt to explain the varieties of faults which may be observed. The reader, however, will clearly see that these dislocations are fortunate for the geologist,

as they have exposed thousands of feet of strata to view which otherwise might have been buried miles beyond possibility of examination. An old wife once declared that she "couldna thole they geologists because they are always looking for faults in the works of God." Poor soul! she did not understand that the faults the

Fig. 3.—Contorted Beds of Limestone and Shale, Lough Shinny, Ireland.

geologist looks for are the orderly products of natural activity and help in the reverent study of Nature.

I will now direct attention to Fig. 3 which represents remarkable results of earth-movements. The figure has been prepared from a sketch of cliffs at Lough Shinny, on the coast of Dublin. The strata consist of beds of limestone and black shale which must once have been flat, but since their horizontal deposition has been contorted so that now they are crumpled and bent at every angle. Mr. A. J. Jukes-Brown, the well-known geologist, says:

(1)

(2)

(1) "Cyclopean Walls," Goatfell (2) Pothole

"The contortion was, in fact, produced by the slow and gradual action of a great force, when the beds, already consolidated, were deep down in the earth, and the superincumbent pressure of the beds above them prevented them from breaking open, as they would have done if the same force had been applied to them at the surface."* This curious effect of earth-movements is not confined to the locality mentioned ; it may be seen elsewhere in Ireland, as well as in Scotland, England, and Wales.

Shrinkage in the size of the earth produces folding of the strata of the crust by lateral compression. If a tablecloth, laid upon a table, be pushed by both hands in opposite directions, a series of folds will be produced. Or a pile of paper, weighted with a book on the top, may be pressed at opposite sides between two books or pieces of wood, and folding will ensue. These simple experiments illustrate the process of folding to which strata have been extensively subjected. Mountain chains are produced by enormous lateral pressure ; evidences of such pressure are to be found in the Alps, where folding of a most complex type has taken place. Fig. 4 shows how beds of rock are folded by earth-movements; a series of domes and troughs is produced. In the domes, or arches, the strata dip away from the crest of the folds, and are described as anticlines (Greek, *anti*, opposite; *klino*, I incline). The anticlines figured are marked A. The troughs of the folds form synclines

* "Manual of Geology," p. 152.

(Greek, *syn*, together; and *klino*), in which the strata dip towards a point, see BB in the figure. Sometimes the folding is not so pronounced, as may be seen from the photograph on Plate III., which illustrates a slight anticline of sandstone beds resting on shale.

It is not difficult for us to realize that the movement which induces folds stretches the rocks at anticlines and even cracks them at the top, and when folded strata are raised to the surface they are more easily attacked by the forces of wear and tear where they are stretched

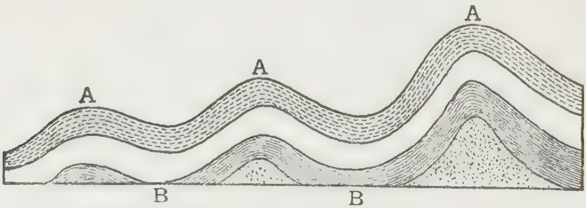


FIG. 4.—DIAGRAM REPRESENTING FOLDED STRATA.
A = Anticline; B = Syncline.

or broken. The folded beds are weakened at the anticlines, but the pressure to which they are subjected at the synclines tends to make the component materials compact and hard in troughs of the folds. In consequence of this action, anticlines are more readily disintegrated and carried away than synclines, and in the course of time a hill-and-valley system is produced in which the synclines are the hills, and denuded anticlines the valleys. Fig. 5 well illustrates the geological results of this action. It represents a section of the strata of South-East England, the section being

cut in a direct line from St. Albans on the north-north-west to the South Downs on the south-south-east. The various strata have been subjected to a lateral pressure which has produced an anticline and a syncline in the section under consideration. The great dome, or arch, of the anticline has been broken and swept away, and now some of the underlying beds are revealed with their edges, or outcrops, at the surface, or just hidden

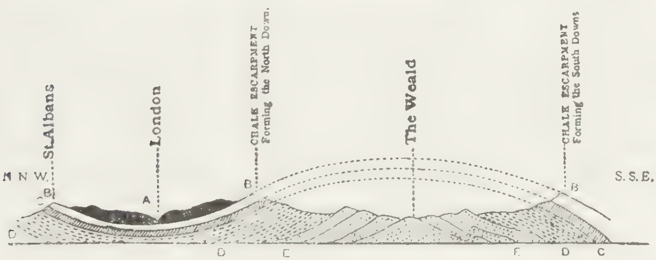


Fig. 5.—Section across South-East England.

A = London clay ; BB = chalk ; CC = lower greensand ; DD = Weald clay mainly ; EE = Hastings sand.

The dotted lines indicate the original upfold of the rocks before erosion took place.

by superficial deposits. The dotted lines in the figure indicate the original condition of the anticline, and show that the two chalk escarpments which form the North and South Downs are outcrops of detached portions of a bed of chalk once continuous, but since removed by denudation of the anticline. Turning to the syncline, in which London is situated, we find that the chalk there, instead of being torn away, as in the Weald, is preserved intact and, indeed, has formed a

bed in which a great mass of the London clay has accumulated. The ancient rocks of the Scottish Highlands have undergone much folding, and, as a general rule, the hills there are composed of rocks which formed synclines. Truly, valleys are exalted and hills abased !

In the North-West Highlands of Scotland geologists have had curious complications of the strata to bewilder them. There are to be found ancient rocks, which ought naturally to be beneath less ancient beds, standing upon strata younger than themselves. How did they get into such an extraordinary position? It has been proved that they have been thrust into it by earth-movements. Some masses have been pushed upwards of twelve miles out of their original positions by a thrust movement. The same remarkable occurrence has taken place in Sweden, where the pressure has been sufficient to move masses of rock for about eighty miles. Can these things be ? Their possibility is not difficult to accept when we think of the great mass of our globe ; besides, they *are*, as is proved by uncontrovertible evidence.

In concluding this chapter, reference must be made to one more effect of earth-movements. I speak of the metamorphism (change in form) of rocks. In sites of great folding, contortion, and pressure, rocks have been so crushed and sheared that their original structure does not now appear. Sandstone grains have been flattened and crushed out of all recognition, and new arrangements of crystals have been induced. The ancient

(1)

(2)

(1) Clohoderick Stone (2) Glacial Detritus

schists of the Highlands are metamorphosed rocks, due in great part, if not entirely, to the crushing and rupturing of strata by great lateral squeezing. But we must bear in mind that metamorphic rocks are due to other contributory causes, some of which are obscure.

CHAPTER IV

EARTH-SCULPTURE

As soon as a land-surface is raised out of the sea it begins to be attacked on its coasts by the waves, and in all parts of its area by weathering and denuding agents. From the sea it rises, and to the sea it must in the end return. It may appear as a solid virgin tableland, or as a chain of mountains, but it will disappear in fragments. There is no tableland that is not being disintegrated, and there are no "everlasting hills." For years it has been my delight to gaze every now and then upon the serrated peaks of the granite hills in Arran. They never present a different form to the eye. Majestic Goatfell has appeared as it is to-day for centuries. But when I climb those glorious hills and scramble over the sharp ridges that connect the heights, I see all around me signs of crumbling and decay. The granite is weathering at a rapid pace; screes and accumulations of its débris are everywhere apparent. In a high wind I have been almost blinded by tiny fragments of this rock being dashed into my face. The

exposed granite is weathering along its joint-planes, and in a great number of places, instead of looking solid, as hard granite is often expected to look, it displays "cyclopean" walls, masses of masonry which, one would think, might have been artificially thrown together did one not know their real character. The photograph on Plate VI. illustrates this type of weathering.

The crumbling of the granite is due principally to alternations of heat and cold. On warm days the surface of the rock becomes heated, and the heat causes expansion of its constituent minerals ; with the return of cold conditions there is a corresponding contraction. Granite is composed chiefly of three minerals—quartz, mica, and felspar. Each one of these minerals expands at a rate different from the other two, and, in consequence, granite is subject to considerable stress under changes of temperature. This stress causes fragments to break away from the surface and accumulate as screes. The fragments are also carried away by high winds, and removed by running water, by which agency they may be carried many miles ; but in transit they are chafed and rubbed, and, from angular fragments of granite, tiny, rounded sand grains are ultimately produced, as well as great quantities of finely worn material which in time settles in lakes and seas in the form of mud.

Mention has been made of joint-planes in granite. It may be said that joints occur in practically all solid

HARDRAW SCAR, YORKSHIRE. MILLSTONE GRIT ON SHALE.

rocks. They are lines of fissure along which the rock breaks quite easily, and as they are both vertical and horizontal they are of great assistance to the quarryman in his work of securing blocks of stone. Granite is an igneous rock; it must at one time have been in a molten condition, and it is probable that its joints are due to contraction on cooling. Now, water makes its way into these lines of fissure; in cold weather it freezes in the joints. Water expands when it freezes, and the frozen water in the joints requires more room than water in its ordinary state. As, therefore, the water expands in the joints as it freezes, it exerts an enormous power which tends to open the joints and force masses of rock apart from each other. As the joints are opened wider, more water penetrates into the crevices, and more water means the exertion of greater force when it freezes. In course of time, in certain situations, masses of rock, weighing many, many tons, may become detached from cliffs and ridges, and fall on to lower ground. In the valleys associated with the granite peaks of Arran, there are countless blocks of granite which have fallen from the peaks and ridges. Some of these blocks are of enormous size and weight, and they are all being gradually disintegrated. I have seen some of them which are literally crumbling into fragments; they have become permeated with water, after the manner of a sponge, and they fall to pieces under the weight of one's body.

On Plate IV. we have a charming picture of Wast-

water in the English Lake District. To the extreme right of the picture will be noted some precipitous cliffs, at the feet of which great screes of material have been formed. The screes are composed of fragments of rock which have become detached from the cliffs. The cliffs at Wastwater, like the granite ridges of Arran, are gradually wearing away; in the slow processes of time, they will disappear.

Stone buildings provide instances of weathering. Old buildings are observed to have lost their surface; their masonry tends to crumble. They are attacked by changes of temperature and also rain. Wind carries away detached fragments. In towns, especially where factories and chemical works abound, the atmosphere becomes laden with gases, some of which are dissolved in rain as it descends from the clouds. The solution acts chemically upon masonry and rapidly destroys its "face." The Glasgow Municipal Buildings have suffered greatly by this weathering.

Rain is responsible for decay of rock surfaces to a larger extent than is commonly realized. The atmosphere always contains a small percentage of carbon dioxide, some of which is dissolved in the descending rain to form carbonic acid. This acid attacks some constituents of rocks, converting them into carbonates, in which form they are soluble in water, which carries them away; the remaining insoluble components are loosened and either washed away by water, or blown off by wind. Thus rain is instrumental in removing the

surface of rocks; as soon as one surface is cleared, another is exposed to attack, and thus the weathering process is continuous.

What may be termed the "etching" power of rain laden with carbon dioxide is markedly apparent in limestone districts. Limestone is composed almost entirely of carbonate of lime, which is wholly soluble in carbonic acid, and consequently rainwater laden with carbon dioxide attacks it at its joints, and etches innumerable channels and gullies. The wonderful caverns of Derbyshire, of which the Peak Cavern is the finest example, are due to water trickling down vertical joint lines of the limestone and making courses underground between the beds of rock. The water dissolves and removes the stone as it flows, gradually enlarges its underground passages, and forms the caverns and tunnels. In the Mountain Limestone, streams commonly disappear into what are called swallow-holes, and rivers are seen to issue from underground. The River Wye emerges from Poole's Hole, near Buxton. The beautiful Derbyshire dales (see Plate V. for picture of Dovedale) have been etched by water, and it has been suggested that some of them were originally caverns, which in the end were so eaten away that the roofs fell in, leaving that picturesque result so admired by the visitor to Derbyshire.

The Alps, the Andes, and the Himalayas are true mountain ranges due to earth-movement, but, although we read of the Scottish mountains, there are no moun-

tains in Scotland in the true sense of the term. True, there are many heights there above 1,000 feet, but they are due to earth-sculpture rather than earth-movement. The characteristic Highland scenery is due to the sculpture of an ancient tableland raised in a mass out of the sea. One has but to stand on a Highland eminence on a clear day to note that the surrounding heights reach a comparative level, and to realize that the hills are due to the scooping out of valleys from a tableland. The principal graving elements have been running water and ice, although the work of sculpture has been assisted by the disintegrating powers of heat and cold, the chemical action of rain, and the transporting power of the wind.

Streams have cut channels along the lines of depressions on the original surface. One may form some idea of the process by observing the behaviour of running water on a road on a rainy day. Observe how the water forms channels, cutting into the surface and transporting material to lower levels. I have seen channels cut inches deep in a single day of heavy rain, and tons of stuff transported by the streams. Roads need to be regularly repaired if they are to be kept in a satisfactory state for traffic. Once running water has found a channel it proceeds to widen and deepen it. The stream eats into its own banks, loosening and carrying away material and causing masses to fall into itself. It carries enormous quantities of stuff in suspension. It urges boulders along its channel and these

knock against each other, fragments being chipped from them in consequence. Gravel, sand, and mud are carried great distances, ultimately reaching the sea. The carried materials, especially boulders and pebbles, are not only worn themselves, but they also assist in wearing the channel as the swiftly flowing water pushes them forward.

Arrived at the edge of a tableland, a stream, augmented by tributaries, and carrying much solid débris, first cuts a gorge, which it gradually opens wider and wider. Cliffs are formed, fragments of which regularly become detached and fall in rock masses and screes. These in turn are broken up and transported, and the gorge gradually widens into a glen or valley. The stream falls on to low ground over a waterfall. At the base of the fall the descending water hollows out a deep pool. Plate VIII. illustrates a waterfall in which the water flows over a bed of Millstone Grit resting on shale. The shale weathers rapidly, much more rapidly than the harder rock by which it is capped. Consequently, as the shale wears away, a ledge of rock projects, and the weight of the falling water gradually breaks this ledge, which falls in fragments. Thus the waterfall gradually recedes, and it is evident that streams cut their way inland. This process is illustrated on a grand scale by the Niagara River with its famous falls. This river has already cut its gorge back from the cliff-face at Queenstown to the extent of six miles. The river flows over a bed of limestone, resting upon shale,

and as the shale wears rapidly away below, projecting blocks of limestone fall from above into the gorge. The fall is receding at the rate of about 4 feet a year, and the time when the gorge will have been cut back to Lake Erie is almost calculable.

The sculpturing power of running water is well illustrated by the Grand Cañon of the Colorado River, which has cut a majestic channel for a distance of three hundred miles. This channel is over a mile below the general surface of the country ; it has been etched by running water.

Rapid streams exhibit another remarkable phenomenon by which their channels are deepened ; I refer to the formation of pot-holes. A pot-hole worn out of hard volcanic rock is illustrated by the photograph on Plate VI. These holes are formed by the grinding action of pebbles and boulders twirled round and round in a whirlpool of water. They are often several feet in depth, and they not uncommonly occur in numbers within a small area. In time the water makes its way through them, breaks down their walls, and thus the channel of a stream in which they occur is deepened.

The carrying power of a rapid stream is remarkable. A Highland burn, rising some 2,000 or 3,000 feet among the hills, descends with great rapidity and force, forming cascades and waterfalls and cutting gorges in its progress. It can hurl along its channel boulders of rock weighing many hundredweights, and the wear and tear along its course is enormous. It has been calcu-

lated that water moving 3 inches per second will carry mud in suspension ; when the velocity is doubled it can carry fine sand. At 12 inches per second it will transport gravel, and at three times this speed it has no difficulty in carrying stones as large as a hen's egg. Every day streams are carrying land-stuff seawards in enormous quantities.

We have spoken of running water as one of the principal agents in sculpturing and dissecting the plateau of the Scottish Highlands, and mentioned ice as another. We must bear in mind that in comparatively recent times there occurred a great glacial epoch, when the whole of Northern Europe was invaded by ice. Then there were glaciers, like those at present in Switzerland, in our own islands. How do we know this ? Well, if we study modern glaciers and discover certain results of their activity, and then in various parts of our country find the results without the glaciers, we justly conclude that those results were caused by glaciers which have disappeared, especially since the same effects cannot be produced by any other known cause. Let us give a little attention to a modern glacier, and then see, from what it is now doing, what glaciers did elsewhere in the Great Ice Age. In a lofty mountain range, such as the Alps, snow which falls in winter is in excess of the quantity which is melted by the summer sun. There snow accumulates year by year and forms snow-fields. Now, it is necessary for the snow to drain off in some fashion ; it does

not all melt ; therefore it must move as a solid. At the bottom of a snow-field the snow becomes converted into ice, which descends very slowly, like some viscid substance, into the valleys. Glaciers are, then, rivers of ice, descending valleys by the force of gravity, and they are the means whereby the snow-fields are drained.

Particularly noticeable on the surface of a glacier are quantities of sand, gravel, and blocks of rock. The rocks of the valleys traversed by glaciers are disintegrated by frost and rain, and the rock débris found on glaciers is the result of this wear and tear. The stones form lines at the sides of the glacier and are called rock-trains, or lateral moraines. Sometimes, however, a line of stones is seen about the middle of a glacier, and this is found to be due to the union of two tributary glaciers, the right-hand moraine of one joining with the left-hand moraine of the other and forming a medial moraine, as illustrated in Fig. VI. Stones thus carried on the surface of a glacier are not worn like those transported in the channel of a stream.

In places, crevasses or fissures are formed in the glaciers, and much rock-stuff falls into these openings to make its way to the under surface of the ice-streams. There they are pressed on to the rock surface of the valley and carried forward by the ice, both grinding and being ground as they proceed. Such stones wear down the rocks of the valley, smoothing and scratching them, and being themselves scratched and polished. Much of the substance of the stones is ground down to sand

and mud. In course of time the ice-stream reaches a warm region where the ice melts and a river is formed. At the end of the glacier a terminal moraine is formed across the valley, consisting of sand, mud, clay, angular rock fragments and polished, scratched stones, derived from the surface, the mass and the "sole" of the ice.

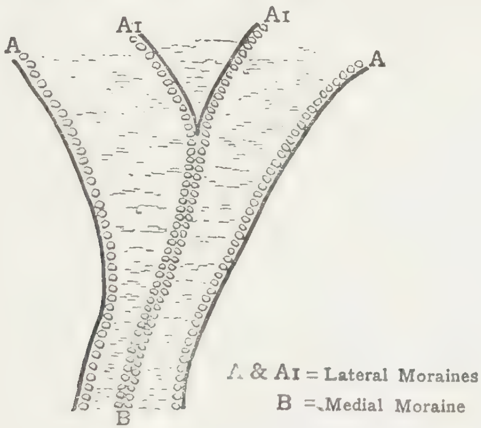


FIG. 6.—DIAGRAM ILLUSTRATING FORMATION OF LATERAL AND MEDIAL MORAINES.

Although much more might be said about modern glaciers, I have called attention to their principal features.

Now, on Plate VII. we have a photograph of the Clochoderick Stone, standing in the parish of Lochwinnoch, Renfrewshire. It is composed of igneous rock, the like of which is not to be found within a distance of three miles. Perhaps it weighs a hundred tons; it stands in solitary glory in a field, the subsoil of which consists

of boulder clay formed by ancient glacial action. How did the stone get to its present position? Undoubtedly it was dropped there by a glacier which no longer exists. The whole district in which the stone occurs shows evidences of past glacial activity. There are polished and scratched rock surfaces, and one can dig out of the boulder clay, any number of stones which have been worn by ice action. And a remarkable assemblage of stones are to be found, many of them quite foreign to the district, and which must have been carried from their parent rocks many miles away. On Plate VII. is a picture of a mass of glacial detritus, a section of which has been exposed in the cutting of a road. Several kinds of polished stones occur in this section. This mass of detritus is one of many to be found near Fort William, Inverness-shire. No glaciers exist in the Highlands now, but that they did once exist is evident in many ways.

In many of our valleys we can find remains of both lateral and terminal moraines. And as to-day glaciers sometimes dam streams by crossing the mouths of valleys, and thus cause lakes, so they must have done in some places in our country in the glacial epoch. There are traces of such a lake in Glen Cloy, Arran; and the remarkable Parallel Roads of Glen Roy, in Scotland, are due to the action of the waves of a glacial lake, which once occupied the glen, but was drained away when the ice barrier melted.

So, like rivers, glaciers are sculpturing agencies. They

have played their part in scooping out valleys and wearing away their rocks; they have also been the means transporting much fragmental rock-stuff. They have materially affected our Highland scenery. Where a valley has once been occupied by a glacier, it has been formed into a trough with steep sides; valleys carved by rivers alone are usually sinuous and have sides with gradual slopes. A glacier tends to cut away projecting spurs, and straighten a valley's course. Glencoe (Plate IX.) is an example of a Highland valley which has been cut by water and straightened by ice, and now that the ice has gone, is being further cut by water, and its steep sides are being gradually reduced by slow denudation.

Plate XVI., which appears on the cover of this volume, provides us with eloquent testimony of the power of the sea, which is attacking coasts the world over. The Needles, near the Isle of Wight, are composed of chalk similar to that which occurs in that island; they indicate that the chalk once extended at least as far out to sea as themselves; they are detached fragments of cliffs, witnessing to a tremendous destruction. The material which once connected them with the Isle of Wight has been removed by the action of the waves. The famous Stacks of Duncansby in Caithness, standing like finger-posts in the sea, were also part of the mainland, but have been detached by sea action. It will be well for us to understand the peculiar action which leads to the formation of such stacks. The sea, striking

the foot of a cliff, in the first instance, will form a small cave. In storms, the waves rush into the cave with great force ; they bear stones, with which they batter the sides of the cave, which, consequently, becomes slowly larger. When high tides occur, the water occupies the cave and advancing waves force it inwards and upwards very powerfully. The air in the cave is much compressed and forced into crevices, and when the waves retreat, the compressed air expands with sufficient violence to break rocks. So the cave increases in size, and sometimes a passage is forced from the cave upwards through the cliff ; in this manner blow-holes, or "bullers," are made. In the course of time the roof of the cave falls in, and then we have an inlet. Several such inlets may be made close together, and the walls of rock between them are duly attacked by the waves, which tend to drill holes through them and so make arches. The material forming the arches eventually falls in, and then nothing is left but stacks or buttresses like the Needles. They, of course, are severely battered, and must at some time disappear.

In considering the depredations of the sea, we have to remember that the waves which trouble the surface of the deep sea do no damage to the sea bottom ; it is only at and near the coast that wave action is serious. Waves, especially during storms, strike the land with terrific impact ; it is a matter of common observation that they grind stones until they are reduced to sand and even finer particles. They form beaches of sand

and shingle, not only out of fragments which fall from cliffs, but also out of material transported by streams. Then the waves roll forward with such power that they can easily lift sand and stones ; these they hurl at the cliffs like shot from artillery, and even the hardest of rock faces cannot withstand such an attack. Acting in this way, the sea, if no barrier intervenes, attacks the bases of cliffs and scoops out hollows, which are overhung by the tops of the cliffs. The overhanging material falls to the shore and is worked upon by the waves, even being used as missiles, and thus made to assist in the dire work of destruction. In cold latitudes the sea often bombards the coast with masses of ice deposited by rivers or formed at the fringe of the sea. Even a balk of timber floating on the sea may be turned into a battering ram, and further the progress of destruction.

> "So swelling surges, with a thundering roar,
> Driven on each other's backs, insult the shore ;
> Bound o'er the rocks, encroach upon the land,
> And far upon the beach eject the sand."

Although the hardest rocks cannot withstand damage and loss due to the bombardment of the sea, it is natural that denudation should proceed most rapidly on coasts where the rocks are easily broken. The east coast of Britain, because the rocks there are softer than on most parts of the west coast, has suffered very conspicuously. It has been asserted that within a century land from Britain has disappeared beneath the waves to the extent

of the County of London. A map of the coast of Yorkshire drawn in 1850, compared with a map made forty years later shows that from the coast south of Bridlington, the sea has removed a strip of land nearly 3 miles long and 100 yards inwards from the site of the 1850 cliff. From Flamborough Head to Spurn Point the land is being removed at the rate of about 2 yards per year. In the course of centuries several towns and villages have disappeared. Ravenspur, where Henry IV. landed in 1399, has completely gone. Yorkshire is known to have lost twelve villages and towns; Suffolk has lost four; and parts of the coast of Suffolk and Norfolk are disappearing to the extent of about 14 feet a year. Nine or ten centuries ago Dunwich, once the capital of East Anglia, was a flourishing city, but by 1349 the sea had swamped a great part of it, and now its chief remains are the ruins of a lonely church resting perilously on the edge of a cliff. What is called Lost Lyonesse, a portion of land between Land's End, the Lizard Point, and the Scilly Isles, disappeared long ago. Nor is the period very remote when Great Britain was continuous with the Continent; the North Sea, the English Channel, and the Irish Sea did not exist, but, in course of time, the sea broke in and surrounded our country. Now it is making serious incursions on our coasts.

On the night of December 31, 1911, a landslide occurred between Folkestone and Dover. Thousands of tons of cliff broke away and fell into the sea. This particular landslide, which happened so recently, reminds

us that landslides have been fairly frequent in the past, and that they are liable to occur on the coasts where hard rocks which are permeable by water rest upon other rocks, such as clays, which are impermeable. The water filters through the surface rocks and gathers on the impermeable strata on which they rest. These strata become slippery or "greasy." The waves of the sea wear away the under strata, and the weight of the upper rocks causes them to break away at some distance inland and slide over the greasy surface of the impermeable strata into the sea.

Elaborate calculations have been made as to the rate at which our land area is being denuded. Taking into account the transport of material in solution, and in suspension by streams, and the depredations of the sea, it is estimated that Britain and the whole of Europe are wearing at such a pace that in less than a million years they will be no more. So the geography of the earth is being constantly changed.

> "There rolls the Deep where grew the tree.
> O earth, what changes hast thou seen !
> There, where the long street roars, hath been
> The stillness of the central Sea.
> The hills are shadows, and they flow
> From form to form, and nothing stands ;
> They melt like mists the solid lands,
> Like clouds they shape themselves and go."
>
> TENNYSON.

CHAPTER V

THE SECONDARY OR STRATIFIED ROCKS: METAMORPHIC ROCKS

Change is universal in Nature, but nothing is lost. The wreckage of the land does not involve loss and inutility of the débris. A grain of sand may be reduced to the finest dust and so be scattered far and wide by the wind, but the substance is somewhere, in some form or other. Detritus which is accumulating in the sea will become hard rock, and earth-movements may raise it above water to become occupied by plants, animals and men. We have already learned that the secondary rocks are so called because their material has been derived originally from primary or igneous rocks; they are also called stratified (Latin, *stratum*, strewn out), because they occur in layers and beds. The stratified rocks may be formed of sedimentary deposits; in some instances they have been formed chemically; and, in the third place, others have had an organic origin.

We shall briefly discuss these three kinds of secondary rocks.

The sedimentary deposits are made by the transport and deposition of broken fragments of primary material, by wind and water. Wind lifts thousands of tons of sand and forms sand-dunes or hills. Rapid streams carry pebbles, gravel, sand, and mud to the sea; even

slow streams make deposits of fine material. Sand is, perhaps, the commonest sedimentary deposit. It is generally formed of worn grains of quartz. Well-rounded grains are usually water-worn. Angular grains give evidence of rocks broken up by quick changes of heat and cold, their little particles being heaped together by wind ; such sands are frequent in dry climates. Other sands are composed of particles of carbonate of lime, derived from broken up shells, corallines, and the limy remains of some seaweeds.

When tiny sand grains, accumulated in great beds under water, are cemented together so as to become solid rock, they form sandstone. The cementing material may be of different kinds ; sometimes it is a sort of clay, or it may be carbonate of lime derived from water, or a compound of iron or silicon. Larger grains than those of which sandstone is composed, are cemented together to form rocks called "grits," of which the Millstone Grit of Derbyshire and Yorkshire is an example. Conglomerate, sometimes irreverently termed "pudding-stone," is a sedimentary rock composed of gravel and shingle cemented by a paste, which may be a kind of clay, or a natural mortar of sand and lime. When angular fragments of rock, such as are found at the bottom of a cliff, are cemented together, they form a rock known as "breccia."

Clay is an important sedimentary deposit. The majority of clays are composed of fine particles of worn felspar, but it may consist of particles of quartz, and

other substances. A running stream carries heavy fragments short distances ; sand is borne farther, and the very fine particles of matter are carried great lengths. The finest particles borne to the sea by streams ultimately drop slowly to the bottom, where they form mud and clay. But clay is also deposited in lakes and in back-waters of rivers. Clay under heavy pressure may be compacted into mud- or claystone. Sometimes it is converted into shale, in which form it splits up into fine plates. Slate is formed when clay has been subjected to very heavy pressure. Clay mixed with lime forms marl, while sand and clay mixed together compose a loam.

Chemically-formed rocks, of a crystalline character, are found interbanded with such sedimentary deposits as sands, clays, and marls. These rocks include gypsums, rock-salt, dolomite, travertine, and some limestones. The materials of which they are composed have been removed in solution from igneous rocks in the first instance, although they are also obtained mediately from secondary deposits. Reference has already been made to the limestone caverns in Derbyshire, which have been formed by water, laden with carbon dioxide, dissolving, and carrying away in solution, great quantities of carbonate of lime. When such water is exposed to the air it loses carbonic acid, and, in consequence of this loss, carbonate of lime is deposited and forms beds of limestone. Petrifying springs deposit carbonate of lime round objects placed in them ; mosses and twigs

(1)

(2)

(1) Mica Schist

(2) Igneous Dyke

become thus petrified and form beds known as "tufa." Deposited carbonate of lime is also carried by streams into lakes and pools, where it falls to the bottom and forms limestone. Travertine, which is a compact crystalline limestone suitable for building purposes, is formed in this way. Dolomite, or magnesian limestone, is a chemically precipitated deposit of carbonate of lime and carbonate of magnesia. Gypsum, from which plaster of Paris is prepared, is a deposit of sulphate of lime; it occurs in inland lakes, and is found in large quantities in the Dead Sea. This deposit, like that of sodium chloride, which forms rock-salt, is due to evaporation of the water in which the salts are dissolved. Gypsum in a pure form becomes alabaster, a stone considerably used for ornamentation ; it is soft and very easily carved. Some iron ores are deposits from water laden with iron salts.

Chemically-formed rocks are not great in quantity when we compare them with the strata otherwise deposited, but they are of great commercial value.

The organically-formed rocks owe their existence to plants and animals, which extract mineral matter from soil and water, and build up skeletons, shells, and tissues therewith. When such organisms perish, their hard parts may remain and accumulate in very thick beds which become compacted into solid rock. Most of the limestones are organically formed, and are composed mainly of the mineral remains of shell-fish. Corals have skeletons of carbonate of lime and the

coral reefs which they build become consolidated into limestone. Sea-lilies, known as Crinoids, are really animals, and their long stems are composed mainly of carbonate of lime; they, too, make a contribution to the limestones. Foraminifera are tiny creatures of no particular organization; they are little masses of living protoplasm, microscopic in size, which form wee shells of carbonate of lime, punctured with pores; through these pores the little creatures thrust wisps of their bodies as a means of swimming and feeding. They exist in incalculable numbers in a living state on or near the surface of the sea, but when they die their wonderful little shells sink and form beds of ooze, which in time become chalk and limestone. Foraminifera deposits are found at a depth of about 1,500 fathoms; beyond that depth they do not occur, probably because any shells which sink deeper are dissolved by the sea-water. Beds of organically-formed limestone are found which are thousands of feet in thickness. The Egyptian Pyramids are built chiefly of limestone formed of shells of Foraminifera, known as "nummulites." But these are of a particularly large kind and not microscopic; they are disc-shaped, about the size of a halfpenny. A photograph of a hand-specimen of nummulitic limestone appears on Plate XV.

Sponges play their part in the formation of organic deposits. Many sponges have a skeleton, consisting of curiously-shaped spicules of silica or flint. These spicules, when the animals die, form deposits which,

when cemented, are called chert. Diatoms are tiny plants with skeletons of silica ; they exist in boundless numbers and a great variety of forms and markings. They occur in both salt and fresh water, and their remains form, in the oceans, beds of diatomaceous ooze, and, in lakes, a deposit called diatom earth. Then the Radiolarians, akin to the Foraminifera, but forming shells of silica punctured with holes, make a contribution of radiolarian ooze, which is deposited on ocean floors at great depths. This variety of ooze may be compacted into chert.

The rocks termed " Carbonaceous " are of organic origin. Their principal constituent is carbon, and they are formed from plant remains. They are of the highest economic value, for they include coal, which is at present our chief fuel. Peat is composed of partly decayed mossy plants. Lignite, or Brown Coal, is composed of decayed vegetation, more chemically changed than that which forms peat. It is intermediate between peat and coal. Coal is mineralized vegetation—that is, decayed vegetable matter that has been mixed up with and buried in sediments, and, under great pressure and some chemical action, converted into its present form.

It is worth while to consider briefly some parts played by plants in geological work. We understand that diatoms form siliceous deposits, and that decayed vegetation may become peat or coal. It should also be noted that when plants occupying marshy places decay, they produce certain acids which act chemically upon salts of

iron contained in rocks under water. The iron is dissolved and removed in solution, but later may be laid down in a new form known as Limonite, or bog-iron ore. If, say, a bean is planted in an inch or so of soil laid over a piece of polished marble, and allowed to grow for six or seven weeks, on removing the marble it will be found that the acid sap has eaten into the polished surface, which will bear a tracing of the roots. This proves that plants secrete acids capable of acting chemically upon rocks. Kerner, the botanist, in his "Natural History of Plants," remarks upon the manner in which lichens etch rocks; he instances the case of a polished marble pillar so etched, and says that these lowly plants attack dolomite, felspar, and even pure quartz. They not only dissolve matter by means of secreted acid, but also loosen particles which are carried away by wind and water.

Soil is largely composed of decayed vegetable matter blended with rock particles. The process of decay liberates organic acids, which are dissolved by water as it percolates through the soil, and carried to the surface of underlying rock, which is attacked and disintegrated to some extent. The roots of plants not only act chemically, they also exert a mechanical force, particularly when they enter cracks in the rock; as they grow they widen the cracks and thus help to break up strata.

It may be noticed that lichens, which are usually the first plants to appear on a newly-exposed rock surface,

(1)

(2)

(1) Volcanic Dyke (2) Volcanic Ashes and Lava

gather a little soil in course of time, in which mosses may grow. The mosses, in turn, gather more material in which higher plants may flourish. Plants also bind the loose materials of soils, preventing them from being shifted by winds. This is particularly evident in the case of sand-dunes formed by wind, and liable to be scattered by the same force. The sand-, or marram-grass, is peculiarly adapted for existence on sand ; it has long creeping underground stems, and where it gets a hold it binds the dunes so that they remain in position and become gradually fitted for occupancy by other plants. In this way, bare shifting sand is changed into dry pasture, and makes excellent golf-links.

Ponds and inland lakes are basins in which detritus of rocks, borne by streams, is deposited ; they also receive deposits of chemical origin. In the experience of man many lakes have been silted up, and their place is now occupied by meadow-land through which streams meander leisurely. It may be said that all lakes are being silted up ; this process is observable in the English Lake District, particularly at Rydal Water (Plate XII.), where solid deposits are rapidly filling the lake-bed and forcing the water elsewhere. Plants materially aid the silting process, in that detritus gathers about them and becomes fixed by their roots. They, so to speak, commandeer the sand and mud, and prevent it from being washed away.

I have already referred to metamorphic rocks (p. 30), and it is sufficient to say here that both primary and

secondary rocks may be so changed by various agencies that they are altered beyond recognition. Metamorphism may be induced by contact with molten rocks, great pressure in the earth's crust, and by earth-movements. Molten rock issuing through a sandstone fissure may alter the sandstone in its immediate vicinity into quartzite. Marble is an altered limestone ; schists may be altered sedimentary or igneous rocks ; while gneiss, so conspicuous in the North-West Highlands of Scotland, is probably a metamorphosed granite.

The metamorphic rocks are regarded as being intermediate between the Primary and Secondary. Many of them are of vast age. They contain no fossils.

The facts contained in this chapter are set down without literary adornment or poetic appeal, but to the thoughtful reader they will suggest nothing short of romance. They illustrate the great patience of Nature in the slow and orderly working out of mighty issues, and that not a grain of sand is wasted. The products of decay and death are made to form the substance of continents. The new order rises, Sphinx-like, out of the ashes of the old.

CHAPTER VI

IGNEOUS ROCKS

The Igneous or Primary rocks have been formed under the influence of great heat ; they are fundamental to the earth's crust, and, as we have seen, have yielded

RYDAL WATER- SILTING UP IN ACTIVE PROGRESS.

the substance from which secondary rocks have been formed. What is the actual condition of deeply buried Igneous rocks we do not know, but we are able to learn something about those which are exposed to view. Moreover, modern volcanic activity enables us to understand similar activity which must have been

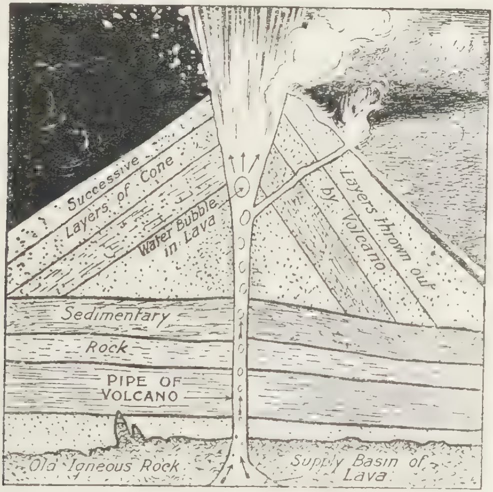


FIG. 7.—IDEAL SECTION OF A VOLCANO.

effective in all geological time, and gives us clues to the interpretation of many commonly-noted facts in relation to the rocks.

The accompanying diagram (Fig. 7) represents a volcano in section, and will enable the reader to realize some of the more important facts of volcanic activity. In the first place it will be noted that the old definition

of a volcano as "a burning mountain" is hardly correct. The so-called mountain is really a cone built by the volcano. Notice, in the diagram, that the pipe of the volcano is represented as passing through a mass of Igneous rock covered with sedimentary strata. The molten matter which rises in the pipe, and often issues from the crater, emanates from a source the depth of which is incalculable. By some means the molten stuff forces an avenue of escape—hence the pipe. When active, the volcano sends out vast quantities of steam and ashes, ejects fragments of rock which fall into the crater, and at periods pours forth streams of lava, which give off gases and steam as they flow. It is to be expected that the matter ejected by the volcano will collect in a conical heap around the mouth, and that the cone will grow with successive eruptions. But it is usual for volcanoes to expel great quantities of fine dust, which often takes a cloudlike form in the air, and may be drifted by atmospheric currents for hundreds of miles. The volcanic cone of Izalco in Salvador is about 3,000 feet above the plain on which it is seated. It is gradually growing, yet 150 years ago it did not exist. This fact will help us to appreciate the probable truth that many volcanic islands existent in the sea were fairly rapidly formed. And the fact that volcanic islands, which are great cones whose tops have been raised above sea-level, exist, proves that volcanic activity may be as common in the sea as on dry land.

Our diagram figures a cone composed of successive

layers of ashes; but matters are not always so simple in volcanic activity. Sometimes flows of lava become interbedded with layers of ashes, and in some instances the cone is shaken and fissured by explosive forces, and the fissures become avenues of escape for steam, ashes, and lava. In such cases, after a period of violent activity, molten matter solidifies in the fissures and assists in holding the cone together.

In the Sandwich Islands there are two volcanoes, Mauna Loa and Kilauea, which eject little, if any, ashes, and exhibit practically no explosive force. In these instances lava flows quite gently.

From the already-noted fact that a volcanic pipe may pass through stratified rocks, the reader will gather that Igneous rocks, rising from a hidden reservoir in a molten form, invade and traverse strata of a secondary character. If there be a simple unbranched pipe when activity ceases, the igneous material will solidify in the pipe, even to the limit of its vent or mouth. The Igneous rock is more durable than the ashes of which a cone is principally formed; in consequence, the cone of an extinct volcano is more rapidly worn away than the plug of hard rock in the pipe. In such a case we may naturally expect to see the plug of a volcano remain long after its cone has disappeared. Now, this is exactly what may be seen in different parts of the world. Not to go from home for examples, mention may be made of the Bass Rock in the Firth of Forth, standing solitary and majestic. This is a plug of Igneous rock which

solidified in the pipe of a volcano. In its case a great mass of stratified rocks through which the pipe passed has been worn away. Edinburgh Castle Rock is of the same description, as also is the remarkable crag which provides such a splendid site for Dunbarton Castle in the Clyde.

In many instances, sheets of lava which poured out of ancient volcanoes have covered and protected stratified rocks, which, without their covering, might have been worn away.

We have abundant evidence that in periods of volcanic activity, the molten rock is not always content to force its way through a simple pipe. It may fracture a cone and eject lava through fissures ; it may also fracture sedimentary strata beneath the cone, and even beyond it, and pour itself forth through openings. Moreover, where the pressure from below is great, and sufficient relief is not given at the surface, the molten material will force itself between beds of strata at considerable depth below the surface.

The igneous material which solidifies in fissures forms "dykes," and that which intrudes itself between beds of strata and there cools, becomes a "sill" or a number of sills. Dykes are vertical, or almost so, while sills, of course, are horizontal, or but slightly inclined. Denudation has exposed many dykes and sills formed in past ages of volcanic action. I have never seen a more remarkable series of dykes than those which are a prominent feature of the southern

shore of the Isle of Arran. They occur there in great numbers, stretching from the cliffs right out to sea. The period in which they were formed was one of great volcanic activity in Scotland. The sedimentary rocks were fissured extensively, and molten rock welled up through the fissures, and poured itself over the surface in great sheets. On the shore referred to the sheets of lava have been worn away, but we have traces of them on the cliffs and among the hills beyond. This reminds us that lavas may be poured forth through fissures and spread out in sheets; cones need not be formed in every instance.

It was probably in some such way that the great lava-sheets of the North of Ireland were produced. The Giant's Causeway, composed of basaltic columns, has been formed from a lava-flow. It must be noted that the surface of a lava-flow cools quickly, while the under-part retains heat for a considerable time. Basaltic lavas tend to assume a columnar structure when they cool slowly, and in the Giant's Causeway we have a lava-flow which cooled slowly in its lower parts, and so became columnar; we have evidence that the upper part of the same flow cooled rapidly, for there still exist detached fragments which are not columnar. Originally, then, the Giant's Causeway was a sheet of lava, the under part of which became columnar, on account of slow cooling, while the upper part, which might deceive us into regarding it as a separate flow, because it cooled quickly, remained an uncolumnar mass. The Island of

Staffa (Plate XIII.), with its famous Fingal's Cave, presents similar features. It is a detached fragment of a lava-flow, and, as the illustration shows, exhibits basaltic columns capped with a covering of tougher basalt. There is little wonder that the early Scots, who observed this island as they sailed from the North of Ireland to Scotland, noticed the similarity of the rock of Staffa to that of the Giant's Causeway. Being unable to account for the similarity in any other way, they concluded that there was a connection between the two places, in the form of a causeway made by giants, along which they could travel to and fro.

We often see dykes of Igneous rock standing up like walls above the strata in fissures of which they were moulded. They stand thus because, being harder than the sedimentary strata to which they are related, they have not been worn so rapidly. The photograph on Plate X. represents such a dyke. In some instances, the dykes wear more quickly than the neighbouring strata ; this may be due to the composition or quality of the igneous material, or to the fact that the molten rock has hardened the adjacent strata by heat, actually making it harder than itself. It may be added that the molten lava of the dykes invariably alters the adjacent strata by heat. Sills of molten stuff intruded between beds of strata effect a similar alteration. In a railway cutting at Arklestone, near Paisley, an intrusion of Igneous rock has been exposed ; it occurs under a bed of coal which it has split in two. The coal has

assumed a columnar structure due to the heat of the intrusion.

The Igneous rocks referred to up to the present point are all classified as Volcanic, a term associated with the mythical Vulcan, a worker in metals who laboured near the earth's surface. All volcanic rocks have solidified at or near the surface. Existing volcanoes enable us to understand much about the volcanic rocks which issued in past ages, but they give no direct evidence concerning rocks which have consolidated under the surface of the earth at great depth and under great pressure. These rocks are called Plutonic, after Pluto, the mythical god of the lower regions. However, we know that volcanic material which cools very rapidly assumes a glassy structure, like that of obsidian; but the more slowly the material cools, and as the pressure of overlying rocks upon it is increased, it becomes more distinctly crystalline. It may be taken for granted that a highly crystalline Igneous rock must have cooled very slowly, the conditions of such cooling being depth below the earth's surface and the pressure of the overlying strata. So Plutonic rocks are highly crystalline; their material has not been able to reach the surface as in the case of volcanoes; it has issued from a profound source in a molten state, but its upward progress has been arrested well within the crust.

Granite is a good and easily-recognized example of a Plutonic rock; it is composed chiefly of quartz, mica, and felspar, which occur as crystals. Quartz is oxide of

silicon ; felspar is a silicate of alumina, combined with silicates of lime, potash or soda ; mica is a silicate of alumina with potash or magnesia. Let a specimen of granite be examined through a magnifying glass. The white or pinkish crystals, oblong in shape, are felspar. The mica crystals may be bronze-black or silvery-white ; they are hexagonal—six-sided. With the point of a knife the mica crystals can be split and layers detached in the form of thin six-sided plates. The quartz appears as a glasslike matrix in which the other crystals are set.

It may be asked why Plutonic rocks so often appear at the surface, seeing that they have been formed at such depth. The area of Dartmoor is 200 square miles, and it consists entirely of granite. The granite peaks of Arran, referred to in a former chapter, are exposed to view, and rapidly disintegrating. The explanation is simple enough. We have treated of earth-movements by which land-surfaces are elevated. By gradual upheaval, rocks, which were formed thousands of feet beneath the surface of the earth, may be raised to a great height above sea-level, and exposed to denudation. By denudation a Plutonic mass may be exposed, or it is possible for such a mass to be pressed upwards, and push aside covering deposits. A mass of deposits has been removed from the Dartmoor granite, and the rugged peaks of Arran are due to the weathering of an elevated mass of granite from which overlying deposits have been carried away.

Classification of Igneous Rocks

In order not to cumber an elementary study, such as we are engaged upon, with technical details, I shall content myself with explaining, in a few words, that Igneous rocks are classified according to the percentage of silica they contain. First, we have Acid rocks containing 66 to 76 per cent. of silica. Granite is typical of this class. Secondly, we have Intermediate rocks, with silica from 56 to 66 per cent.; and, thirdly, there are the Basic rocks, with a percentage of silica ranging from below 40 to above 50. Syenite, a Plutonic rock, is a typical Intermediate, and the Basic series is well represented by gabbro.

Now, the Plutonic rocks have volcanic representatives which agree with them in composition, but not in appearance. What is meant is that molten matter, which solidifies deep beneath the surface as a Plutonic rock, highly crystalline, will cool as a lava, should it reach the surface. The lava and the plutonic mass, formed from the same substance, disagree in appearance. By way of illustration, if you make a saturated solution of alum and divide it into two portions, and evaporate the water of one portion quickly, and of the other slowly, in the former case you will get small, and in the latter large, crystals. The material is the same in both instances, although the crystals vary in size. Now, if igneous matter of the acid type cool slowly in a deep-seated situation, the product will be granite. The same material cooling more rapidly and with less pressure will yield a liparite, a lava associated with the volcanoes

of the Lipari Isles ; hence its name. Obsidian, a glassy product, will be the result if the material cools very rapidly under certain conditions. Syenite, trachyte, and pitchstone are similarly related Intermediate rocks, and gabbro, basalt and tachylyte are a series of the Basic. Bulk for bulk, the Basic rocks are heavier than the Intermediate, and the Acid rocks are the lightest of the three. Thus, a cubic foot of gabbro will weigh about 180 lbs., whereas a similar bulk of syenite and granite will weigh 175 and 165 lbs. respectively.

Beds of volcanic ash are sometimes seen interbedded with sedimentary deposits. The ash beds indicate periods of volcanic activity, while each bed of sediment stands for a period of volcanic rest and gradual deposit of sedimentary material. The photograph on Plate XI. shows a lava-flow resting upon a bed of ash, and covered with another bed of the same material. The picture testifies to the near neighbourhood of an erst-time volcano, which at one period ejected large quantities of ash, then belched forth a mass of lava, and, subsequently, a further moiety of ash.

CHAPTER VII

CHAPTERS OF THE EARTH'S HISTORY

In concluding our study of the romance of the rocks, we shall touch briefly and lightly upon an amazing record—a record which is not complete in every detail,

but yet sufficiently clear to give us a conception of the grand procession of life-forms from the most remote times to the present day.

Furnished with hammer, chisel, and haversack, the student of the rocks may find himself in a situation recalling Crabbe's lines:

> "It is a lonely place, and at the side
> Rises a mountain in rugged pride;
> And in that rock are shapes of shells, and forms
> Of creatures in old worlds, and nameless worms;
> Whole generations lived and died, ere man,
> A worm of other class, to crawl began."

Using his hammer and chisel patiently and skilfully in splitting the rocks, he may bring to view "shapes of shells and forms of creatures in old worlds" which will appeal to his imagination, and help him to picture the life of past ages. The finding of a fossil, to me, is always accompanied with a thrill. We may scan memorials of ancient human handiwork and find it highly interesting and instructive; it takes us back centuries, or a few thousand years at most; but a fossil may be the remains of a plant or animal that existed incalculable years ago, and became extinct before man made his bow in the arena of Nature. For thousands of species of life-forms have made their entrances and exits; they have "had their day and ceased to be."

A fossil, literally, is something dug up, and the term applies to remains or impressions of animals and plants which are found in rocks, or naturally placed amongst clay, sand, or gravel. A petrified tree-trunk is a fossil,

and so is the impression in limestone or shale of a shell or a fern. The rocks have preserved in them burrows of worms, footprints of birds and other animals, and even impressions of rain-drops, as well as ripple marks made on sand by waves, and sun-cracks : these are all called fossils. The fossils preserved in the rocks are only a slight indication of the number and variety of living creatures which occupied the world in past ages. The bodies of many creatures are too perishable to become fossilized, except under very particular circumstances. Fossils teach us much about the story of Creation ; they also give us clues to the geography of the age in which the creatures they represent lived, and show us how there have been changes in geography. Chalk was formed in the sea, and when we find chalk with its characteristic fossils high and dry, we know that it once occupied part of a sea-bed. But, to the geologist, the most important use of fossils is founded on the fact that certain kinds are associated with particular formations of strata. They indicate the relative ages and succession of the rocks, and help us to determine the place, or "horizon," of the strata in which they are found. Thus, if we find fossils typical of particular rocks in England, and afterwards discover rocks bearing similar fossils at the Antipodes, we know at once that both sets of rocks are of the same age.

One might say that the story of the earth is inscribed in several books, each book containing chapters, and each chapter being composed of sections. The books

are made of stone. Each book tells the story of an Era embracing vast time, and each chapter deals with a Period of the Era; again, each section of a chapter has reference to a subdivision of a Period.

Let it be understood that the stratified rocks have been deposited through incalculable time. The oldest of them are so old that it were foolish to even guess their age in years. But we know something of the order in which they were deposited, and their fossil contents enable us to decide which rocks are very old, which are less old, and which are of comparatively recent date. The geologist treats of four great Eras in the history of the earth:

1. Eozoic (Greek, *eos*, dawn; *zoe*, life).
2. Palæozoic (Greek, *palaios*, ancient; and *zoe*).
3. Mesozoic (Greek, *mesos*, middle; and *zoe*).
4. Cainozoic (Greek, *kainos*, recent; and *zoe*).

The Eozoic rocks yield traces of extremely simple forms of life; their scanty record deals with the dawn of living creatures and plants. The rocks of the Palæozoic Era gives us information concerning life-forms of very ancient date; indeed, they yield fossils of the most ancient creatures of which we have distinct knowledge. The Mesozoic Era is the middle age of geological history; while the Cainozoic strata include remains of recent forms of life.

The Eozoic rocks are as a book composed of one long chapter, which we call the Archæan Period. It is

estimated that the Archæan (Greek, *archaios*, ancient) strata are no less than 50,000 feet in thickness. The lower Archæan rocks mainly consist of metamorphosed igneous and sedimentary rocks, such as the gneisses and schists of the Scottish Highlands, which are the oldest rocks of which we have any knowledge. They contain no fossils, not necessarily because plants and animals did not exist when they were formed, but because they were either too perishable to leave remains, or, if they did become fossilized, the deposits in which they were preserved have been subjected to such alteration that the remains have been mutilated beyond recognition. The upper Archæan rocks include quartzites, crystalline limestones, some fine-grained gneisses and schists, and, in addition, some unaltered shales, sandstones, and conglomerates. The unaltered rocks yield traces of life. Some seams of limestone amongst them are probably of organic origin. A fossil Crustacean has been recognized in rocks of this age in Montana, and the Torridon sandstone of the North-West Highlands of Scotland has yielded grains of phosphate which are suspected to be organic in nature. Archæan strata are represented in North-West Scotland, Shropshire, Warwickshire, Worcestershire, Leicestershire, as well as in Canada, Scandinavia, and elsewhere.

The Palæozoic Era embraces six periods—the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. It is like a book of six chapters.

The Cambrian Period is named after Cambria, the

old-time name of Wales. The rocks of the period are typically developed in North Wales, but they occur also in North-West Scotland, England, Ireland, North and South America, and elsewhere. The deposits of the period occur principally as slates, sandstones, and flagstones; limestones are not abundant. The rocks of this age have been much altered by earth-movements, and there was considerable volcanic activity during the period. The strata are estimated to be 12,000 feet in thickness. Trilobites are the characteristic fossils of the Cambrian rocks; their name indicates three-lobed creatures; they belonged to the Crustacea, a class of the animal kingdom which embraces crabs, lobsters, crayfish, shrimps, wood-lice, and water-fleas. They probably lived in great numbers on muddy and sandy sea-floors. They became extinct in Permian times. A particular genus of Trilobites, named *Olenellus*, is typical of the lowest zone of Cambrian rocks. *Olenellus* seems to have been ousted in favour of another genus, *Paradoxides*, which marks the middle Cambrian strata, while the Upper Cambrian zone is known by the genus *Olenus*, which seems to have superseded *Paradoxides* in later Cambrian times. But the Cambrian rocks yield other fossils besides Trilobites; for instance, remains of sponges, starfish, crinoids, some molluscs and worm-tracks, have been found in them.

A few fossils of the Cambrian Period are represented in Fig. 8. Three genera of Trilobites are figured by *a b*, and *c* : *a* is known as *Conocoryphe Lyellii*, the first,

or generic, name meaning "cone-head," and the second, or specific name, "of Lyell," it having been given in honour of the great geologist, Sir Charles Lyell ; *b* is called *Microdiscus sculptus*—that is, "the sculptured little disc." Both these fossils are from the Harlech group of Lower Cambrian rocks in Pembrokeshire. It will be observed from the figures that *Conocoryphe* has

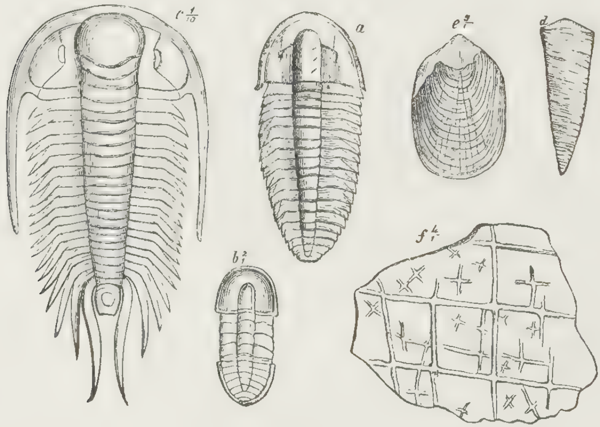
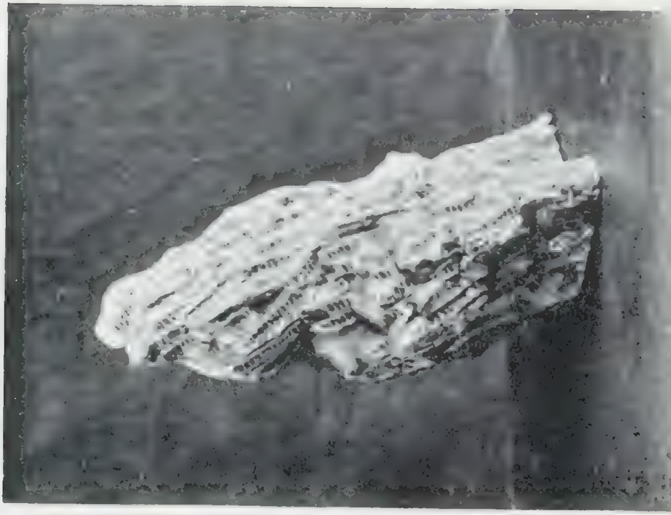


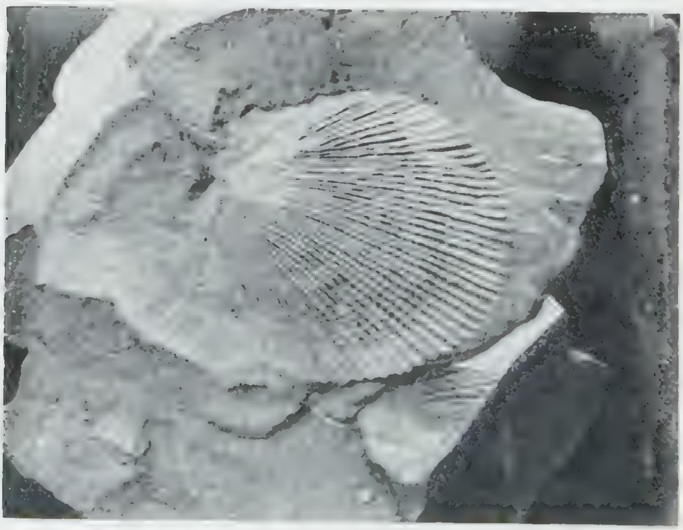
FIG. 8.—SOME CAMBRIAN FOSSILS.
For description see text.

more numerous segments than *Microdiscus*. The third Trilobite in the illustration, *c*, is drawn one-tenth of the natural size ; it is *Paradoxides Davidis*. The generic name means "prodigious forms," and *Davidis*, "of St. David's" ; in fact, this species is found nearly 2 feet long. Along with other large Trilobites, *P. Davidis* is found in Pembrokeshire in the Menevian beds of

PLATE 14



Fossil Coral



Fossil Pecten

Cambrian Age. The remaining fossils in the same illustration are: *d*, *Theca corrugata* (*Theca*, a sheath; *corrugata*, wrinkled), the remains of a little Pteropod (wing-feet), and belonging to a class of animals which floats on the ocean; *e* represents *Lingulella ferruginea* (rust-coloured little Lingula), a bivalve mollusc of a lower grade than our common cockle; and *f*, which is drawn larger than natural size to show detail, indicates the structure of a sponge which has been named *Protospongia fenestella*, the generic name meaning "first sponge," and the specific, "little window."

The Ordovician rocks get their name from the Ordovices, a tribe once occupying territory in Shropshire and Eastern Wales, where the strata of the period are typically developed. They consist of grits, quartzites, flagstones, shales, slates, sandstones, with one or two beds of limestone; their estimated thickness is 15,000 feet; they occur in Shropshire, Wales, the Lake District, and Southern Scotland. The fossils characteristic of these rocks are graptolites (Greek, *grapho*, I write). These fossils represent marine animals allied to the common sea-fir; they lived in colonies in a series of horny cups attached to a horny rod, each animal probably being in appearance somewhat like a hydra. Graptolites are found among Ordovician shales; many of them have been replaced by iron pyrites, and they look like gilded designs on a black background. They get their name from a fancied likeness of some of them to a quill-pen. There was great volcanic activity in

Ordovician times, notably in the Lake District and North Wales.

The strata of the Silurian Period are estimated to be 7,000 feet in thickness ; they consist of shales, slates, limestones, mudstones, conglomerates, and sandstones. They are named after the Silures, who in Roman times held part of Shropshire and Central and South Wales. The fossils of the period indicate a great development and advance of life-forms. They include the earliest traces of land-plants, a wealth of corals, a number of marine scorpions, a considerable variety of molluscs, crinoids, and, what is of the greatest interest, the oldest known kinds of fish and insects. It would seem that in the Silurian fish we have the first appearance of vertebrate, or backboned, animals. Silurian rocks appear in Shropshire, Wales, the Lake District, South Scotland, Scandinavia, and elsewhere.

The Devonian Period, with strata 5,000 feet thick, is represented by rocks in Devonshire and Cornwall as well as in Wales and Scotland. In Devonshire and Cornwall the rocks are distinctly of marine origin. They get their name from Devonshire, where they were first studied. The rocks of the period which occur in Herefordshire, Scotland, and South Wales, and comprise brown, red, and white sandstones, conglomerates, red marl and cornstones (impure limestones), are known as the Old Red Sandstone strata ; they appear to have been deposited in great inland lakes. This period is characterized as the "Age

of Fish." The Devonian fish were principally of the ganoid, or "armoured," type, being protected by a set of horny "armour-plates." They have few living representatives, the sturgeon being one, and the

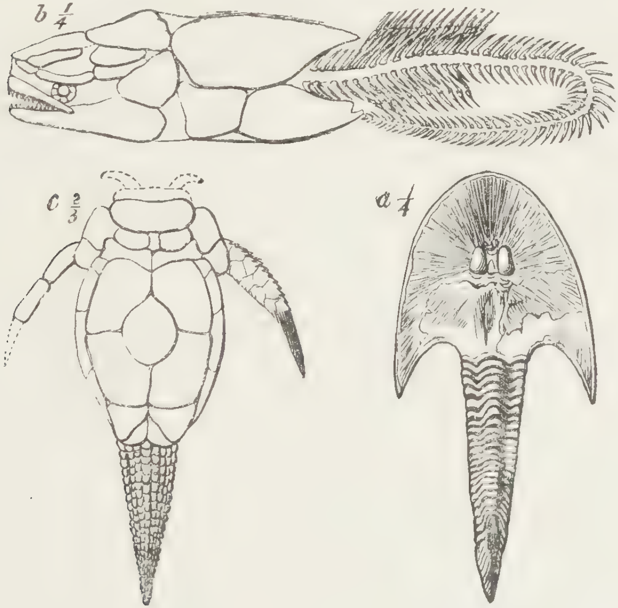


Fig. 9.—Fossil Fish of Old Red Sandstone Age.
See text for description.

garpike, which is found in American lakes, another. There was extensive volcanic activity in Devonian times.

In Fig. 9 we have illustrations of the fossil forms of three species of ganoid fish of Old Red Sandstone Age :

a and *b* are drawn one-quarter of their natural size, while *c* is reduced to two-thirds. The first, *a*, is named *Cephalaspis* (head-shield) *Lyellii* (after Lyell); *b* is *Coccosteus* (berry-bone) *decipiens* (deceptive); and *c* is *Pterichthys latus* (broad wing-fish). Fossil remains of these armoured fishes have been found in large numbers in the Caithness flagstones; the celebrated Scotsman, Hugh Miller, discovered a great many, and one (*Pterichthys Milleri*) has been named after him.

The next period, the Carboniferous, is famous for its coal-seams, and deposits of ironstones, shales, fireclays, and limestone, which, on account of their economic value, have been extensively "worked" and so laid bare for study. The strata, which are said to total 12,000 feet in thickness, are found in Wales, Lancashire, Derbyshire, Yorkshire, Northumberland, Central Scotland, and in various parts of the world. The Carboniferous limestone is at least 2,000 feet thick in Derbyshire; it was laid down under marine conditions. The climate of Carboniferous times, in Great Britain, must have been warm and humid, otherwise it would not admit of the remarkable development of vegetation which occurred then. The flora of the period was most remarkable; there were no flowers as we commonly understand them, but clubmosses and horsetails grew to the dimensions of forest trees; roots, trunks, and leaves, as well as their fruits, are found in fossil state. In the flora of our own day these plants are represented by the clubmosses of dwarf stature which grow on our

northern hills, and various species of horsetail which are seldom to be found more than 2 or 3 feet high. There were also ferns and other flowerless plants in those ancient times.

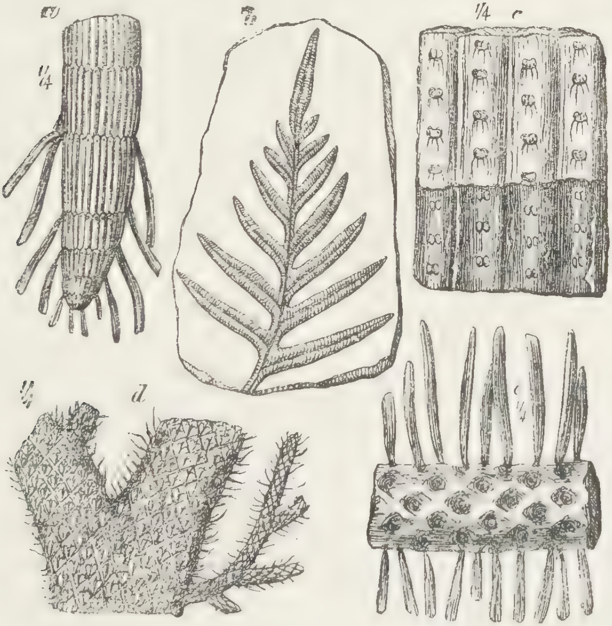


Fig. 10.—Carboniferous Plants.
See text for description.

Some fossil forms of Carboniferous plants are shown in Fig. 10. The drawing, *a*, which, it will be observed, is reduced to quarter-size, represents a portion of one of the Carboniferous Horsetails just spoken of; it is named *Calamites cannæformis*, which means the

"cane-shaped reed-stone." The fern-like fossil, *b*, is a portion of a leaf of a plant named *Alethopteris lonchitica.* The term *Alethopteris* means "true fern," and early investigators regarded the fossil as being the remains of a fern. Recent discoveries, however, lead us to believe that the plant represented was not a fern, in spite of its fern-like leaves; indeed, it was a seed-bearing plant, and its seeds were very different from the minute spores produced by ferns. The figure *d* in the same illustration gives a good idea of one of the Clubmosses of Carboniferous times; it is called *Lepidodendron elegans* (the graceful Scale-tree). Seed-cones of these plants have been found in great numbers. Figs. *c* and *e*, which, like *d*, are reduced to quarter-size, really represent two parts of the same plant, although they have differenat names: *c* is *Sigillaria reniformis* (*Sigillaria*, seal-stamped; *reniformis*, kidney-shaped); *e* is *Stigmaria ficoides* (*Stigmaria*, pitted plant; *ficoides*, fig-like). *Sigillaria* is said to be the stem of the plant, while *Stigmaria* is considered to be the root. The drawing shows rootlets which must have pushed their way into the mud in which the tree grew. A trunk of *Sigillaria reniformis* has been found in Germany, near Saarbrücken, in the situation in which it must have grown; it measured 6 feet in diameter at the base from whence the roots proceeded. Many other large specimens of this order of plant have been found, and it is evident that the *Sigillariæ* are to be accounted among the largest trees of the period.

Thousands of species of Carboniferous fossils have

been found, including some fishes, scorpions, and, what is of greater interest, Labyrinthodonts, which were cold-blooded animals capable of living both in water and on land; they must have been somewhat like our modern newts and salamanders. They varied in size from an inch or two in length to about 8 feet. The cumbrous name given to these creatures means "labyrinth-toothed," because cross-sections of the teeth of most of them show mazelike patterns. These animals seem to have been the most highly developed creatures of Carboniferous times, and it was during those times that they made their first appearance. The coal, so intimately associated with this period, was formed from the decayed vegetation, which seems to have grown and perished in warm swamps, although some of it may have resulted from accumulations of drift-wood transported by currents of water.

The Palæozoic Era concluded with the Permian Period, the rocks of which are named after Perm in Russia, where they are typically developed. The estimated thickness of the strata is 1,500 feet, and they include red sandstones and marls, magnesian limestone, marl, slate, and breccias. The rocks seem to have been deposited in inland salt lakes; they occur in parts of England and scantily in Scotland. The chief interest of the period to the student of the development of life-forms is centred upon the fact that the first reptiles appear in Permian times.

The Mesozoic Era, the geological "middle ages,"

included three great periods—the Triassic, Jurassic, and Cretaceous. The era was the age of great reptiles.

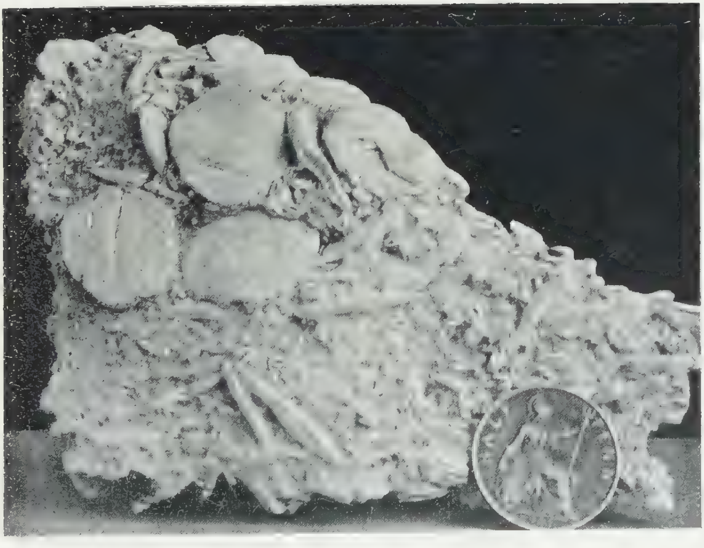
The rocks of the Triassic Period attain an estimated thickness of 3,000 feet ; they consist of mottled sandstones, pebble beds, waterstones, new red marls, shales, and limestones, and are sometimes called the "New Red Sandstone." The name "Triassic" originated in the threefold development of rocks of the period in Germany. The New Red Sandstone strata yield abundant gypsum and rock-salt in Worcestershire and Cheshire, and these deposits indicate a dry climate such as that now prevailing in the region of the Dead Sea. The British deposits of the period yield few fossils, but they show traces of great land animals, which literally left their footprints in the sands.

The Labyrinthodonts, which have been mentioned as existing in the Carboniferous Period, seem to have persisted to the end of the Triassic Age, when they appear to have become extinct. In Fig. 11, *a*, *b*, and *c* represent respectively the footprints, the head, and a tooth, of *Labyrinthodon giganteum* found in Triassic strata. Footprints of animals, forming tracks over 20 feet long, were, about the year 1838, found at the Stourton Quarries, near Liverpool ; Mr. Jukes, in his "Manual of Geology," says the quarrymen supposed they were the marks of "some one crawling away from the Deluge." The drawing *d*, in Fig. 11 represents a Triassic fish, *Dipteronotus cyphus*.

The Jurassic rocks, named after the Jura Mountains,

(1)

(2)



(1) Ammonite (2) Nummulitic Limestone

where they are well developed, are estimated to be 5,000 feet in thickness. They consist of beds of clay, limestone, and sand, and include the oolites and the lias. They occur in Dorset, Somerset, Oxfordshire, Northamptonshire, Yorkshire, and elsewhere in England,

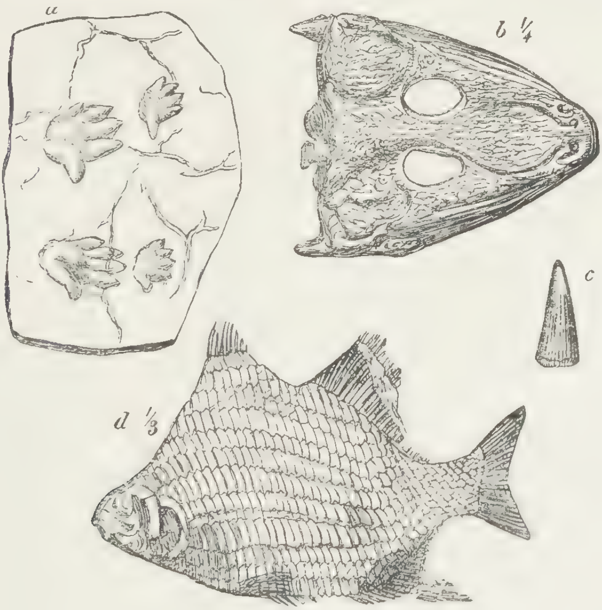


FIG. 11.—SOME TRIASSIC FOSSILS.
For description see text.

but are poorly represented in Scotland. Reptiles reached their greatest development in Jurassic times ; then the deinosaurs (Greek, *deinos*, terrible ; *sauros*, lizard) flourished mightily, some of them attaining

enormous proportions. Ammonites and belemnites abounded in the Jurassic seas, and their fossil remains are typical. Ammonites have modern representatives in the pearly nautili of the Pacific and Indian Oceans. The cuttle-fish is a living relation of the extinct belemnites. Birds of rather clumsy build made an appearance in Jurassic times.

The Cretaceous Period gets its name from the chalk (Latin, *creta*) conspicuous among its deposits, which are said to attain a thickness of 2,500 feet. In England the chalk appears in Yorkshire, and is easily traced through Lincolnshire, Norfolk, Suffolk, Cambridge, Bedford, Hertford, Buckingham, Oxford, Berkshire, Wiltshire, and Dorset. It also appears in Sussex, Kent, Surrey, Hants, and the Isle of Wight. The Cretaceous fossils are closely allied to those of the Jurassic Period. Remains of some great deinosaurs have been found in the Weald.

In Fig. 12 we have drawings of some fossils found in the Lower Greensand beds, which were formed in Cretaceous times. These beds were evidently deposited in a sea, for the fossils contained in them are of a marine type. The strata include sand and sandstones stained with iron, and thus yellow or brown in colour. They get their name from the green-coloured grains of glauconite which they frequently contain. The beds occur in the Weald, where they appear above the Weald Clay, in the Isle of Wight, in the counties of Oxford, Bedford, Buckingham, Cambridge, and Norfolk;

they are also thick in Lincolnshire. The fossils figured are—*a*, *Holocystis elegans*, a coral; *b*, *Rhynchonella* (little beak) *Gibbsii*; *c*, *Terebratula* (perforated shell) *sella* (like a chair)—these two are shells of Brachiopod molluscs. *d*, *Exogyra* (curved outwards) *sinuata*

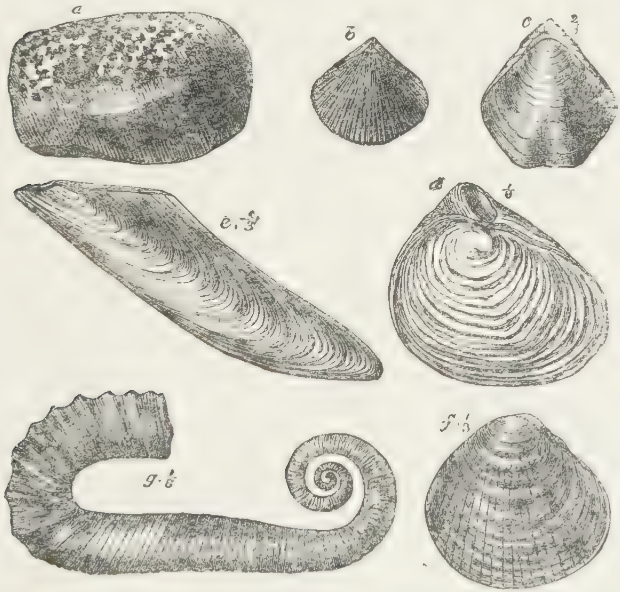


FIG. 12.—SOME LOWER GREENSAND FOSSILS (CRETACEOUS PERIOD). For description see text.

(twisted), related to the oyster; *e*, *Gervillia* (from M. Gerville) *anceps* (doubtful); *f*, *Sphæra corrugata* (corrugated round shell)—these three shells belong to the bivalve molluscs. The drawing *g* represents *Ancyloceras gigas* (gigantic curved horn), the remains

of an animal belonging to the same order as the ammonites. It might be regarded as an ammonite which had not adopted the habit of rolling itself up.

The Cainozoic Era is represented by rocks enclosing fossils of recent, although not always existing, forms of life. The periods of this era are the Eocene (Greek, *eos*, dawn ; *kainos*, recent), in which existing species of shells begin to appear ; the Oligocene (Greek, *oligos*, few ; and *kainos*), when there were few recent shells ; the Miocene (Greek, *meion*, less), when there were really more recent forms, but they totalled less than older species ; the Pliocene (Greek, *plios*, more), when shells of existing species came to be more in proportion to the old shells ; and the Pleistocene (Greek, *pleistos*, most), the shells of this period being represented by still living species. This era is known as the "Age of Mammals," for horses, mammoths, elephants, and a host of other mammals came into being in Cainozoic times. To be exact, mammals made their first appearance at the commencement of the Mesozoic Era, but in those earlier times they were few and must have had a hard struggle for existence. Yet they were destined to become dominant, and the hitherto supreme reptiles gave place to them in Cainozoic times. Mammals, with man at their head, are the most highly developed animals, and it is significant that they did not appear in strength until recent geological times. The reader should study the geological map of the British Isles which appears on p. viii ; it will enable him to see how

the rocks of various periods are distributed within the area. A Britisher is fortunate in living in a region which includes so many geological formations.

The foregoing rapid and by no means complete survey of geological history brings home to one an appreciation of the wonderful procession of life-forms. The simplest and lowliest creatures are represented in the oldest rocks, and, as we ascend the formations from the oldest to the most recent, we find evidences of a gradual increase in the variety of animal and plant life, as well as of more perfect and complex life-forms. In fact, in ascending the formations we also ascend the scale of creation. In the older rocks we find fossils of Foraminifera, Radiolarians, Sponges, Graptolites, Corals, Starfish, Sea-lilies, Worms, Trilobites and Molluscs. Then, a little higher in the scale, we discover fish, to be followed higher still by Amphibians. The reptiles are even more recent, not appearing until Permian times. Birds are found for the first time in Jurassic rocks, although they may be a little older. Then, lastly, we have the Mammals, with their highest representative, Man, as the king and crown of creation. The most highly developed animals and plants were the last to appear ; creation has been a gradual unfolding and a wonderful growth—first the seed, then "the blade, the ear, and the full corn in the ear."

Verily, the romance of the rocks is as wonderful as the romance of human life. The story is not yet complete, for, old as it is, the earth is young. There are

chapters yet to be written, during the æons of the future, ere, in the somewhat altered terms of Shakespeare,

> This great globe and all that it inhabit shall dissolve,
> And, like the baseless fabric of a vision,
> Leave not a rack behind.

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